U.S. Department of the Interior
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Data on Streamflow and Quality of Water and Bottom Sediment in and near Humboldt Wildlife Management Area, Churchill and Pershing Counties, Nevada, 1998–2000

Open-File Report 03–335

Prepared in cooperation with the
U.S. FISH AND WILDLIFE SERVICE
BUREAU OF RECLAMATION
NEVADA DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

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By Angela P. Paul *and* Carl E. Thodal

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Carson City, Nevada
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CONVERSION FACTORS, VERTICAL DATUM AND ABBREVIATED WATER QUALITY UNITS

Multiply	By	To obtain
acre	4,047	square meter (m^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot per day (acre-ft/d)	0.001233	cubic hectometer per day (hm^3/d)
acre-foot per month (acre-ft/mo)	0.001233	cubic hectometer per month (hm^3/mo)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)
cubic foot per second (ft3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
tons per day (tons/day)	907.2	kilograms per day (kg/day)

Temperature: Degrees Celsius (^oC) can be converted to degrees Fahrenheit (^oF) by using the formula $^oF = [1.8(^oC)]+32$. Degrees Fahrenheit can be converted to degrees Celsius by using the formula $^oC = 0.556(^oF-32)$.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Abbreviated Water Quality Units:

g	(gram)	mm	(millimeter)
g/min	(gram per minute)	mg/kg	(milligram per kilogram)
L	(liter)	mg/L	(milligram per liter)
µg/g	(microgram per gram	ng/g	(nanogram per gram)
µg/L	(microgram per liter)	ng/L	(nanogram per liter)
µS/cm	(microsiemens per centimeter at 25^o C)	pCi/L	(picocurie per liter)

Data on Streamflow and Quality of Water and Bottom Sediment in and near the Humboldt Wildlife Management Area, Churchill and Pershing Counties, Nevada, 1998-2000

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ABSTRACT

This study was initiated to expand upon previous findings that indicated concentrations of dissolved solids, arsenic, boron, mercury, molybdenum, selenium, and uranium were either above geochemical background concentrations or were approaching or exceeding ecological criteria in the lower Humboldt River system. Data were collected from May 1998 to September 2000 to further characterize streamflow and surface-water and bottom-sediment quality in the lower Humboldt River, selected agricultural drains, Upper Humboldt Lake, and Lower Humboldt Drain (ephemeral outflow from Humboldt Sink).

During this study, flow in the lower Humboldt River was either at or above average. Flows in Army and Toulon Drains generally were higher than reported in previous investigations. An unnamed agricultural drain contributed a small amount to the flow measured in Army Drain.

In general, measured concentrations of sodium, chloride, dissolved solids, arsenic, boron, molybdenum, and uranium were higher in water from agricultural drains than in Humboldt River water during this study. Mercury concentrations in water samples collected during the study period typically were below the laboratory reporting level. However, low-level mercury analyses showed that samples collected in August 1999 from Army Drain had higher mercury concentrations than those collected from the river or Toulon Drain or the Lower Humboldt Drain. Ecological criteria and effect concentrations for sodium, chloride, dissolved solids, arsenic, boron, mercury, and molybdenum were exceeded in some water samples collected as part of this study.

Although water samples from the agricultural drains typically contained higher concentrations of sodium, chloride, dissolved solids, arsenic, boron, and uranium, greater instantaneous loads of these constituents were carried in the river near Lovelock than in agricultural drains during periods of high flow or non-irrigation. During this study, the high flows in the lower Humboldt River produced the maximum instantaneous loads of sodium, chloride, dissolved solids, arsenic, boron, molybdenum, and uranium at all river-sampling sites, except molybdenum near Imlay.

Nevada Division of Environmental Protection monitoring reports on mine-dewatering discharge for permitted releases of treated effluent to the surface waters of the Humboldt River and its tributaries were reviewed for reported discharges and trace-element concentrations from June 1998 to September 1999. These data were compared with similar information for the river near Imlay.

In all bottom sediments collected for this study, arsenic concentrations exceeded the Canadian Freshwater Interim Sediment-Quality Guideline for the protection of aquatic life and probable-effect level (concentration). Sediments collected near Imlay, Rye Patch Reservoir, Lovelock, and from Toulon Drain and Army Drain were found to contain cadmium and chromium concentrations that exceeded Canadian criteria. Chromium concentrations in sediments collected from these sites also exceeded the consensus-based threshold-effect concentration. The Canadian criterion for

sediment copper concentration was exceeded in sediments collected from the Humboldt River near Lovelock and from Toulon, Army, and the unnamed agricultural drains. Mercury in sediments collected near Imlay and from Toulon Drain in August 1999 exceeded the U.S. Department of the Interior sediment probable-effect level. Nickel concentrations in sediments collected during this study were above the consensus-based threshold-effect concentration. All other river and drain sediments had constituent concentrations below protective criteria and toxicity thresholds.

In Upper Humboldt Lake, chloride, dissolved solids, arsenic, boron, molybdenum, and uranium concentrations in surface-water samples collected near the mouth of the Humboldt River generally were higher than in samples collected near the mouth of Army Drain. Ecological criteria or effect concentrations for chloride, arsenic, boron, molybdenum, and selenium were exceeded in samples collected near the mouths of the Humboldt River and Army Drain.

Bottom sediments collected from Upper Humboldt Lake had arsenic, cadmium, chromium, copper, and nickel concentrations that either approached or exceeded biological-effect concentrations and/or Canadian Interim Freshwater Sediment-Quality Guidelines. All other wetland sediments collected during this study had constituent concentrations within acceptable limits.

INTRODUCTION

Background

The Humboldt River headwaters are in northeastern Nevada and the river flows southwest through the Lovelock Valley, discharging into the State's Humboldt Wildlife Management Area (HWMA) in the Humboldt Sink south of the town of Lovelock (fig. 1). The HWMA includes wetland habitat important for local wildlife and migratory birds traveling the Pacific Flyway, and also provides recreational access to hunters, fishermen, and bird watchers. The HWMA has been identified as one of the most important wetlands in Nevada (Seiler and Tuttle, 1997). Inflow to the HWMA is dominated by irrigation drainage and spill water from Rye Patch Reservoir. There is concern regarding general water and sediment quality within the lower Humboldt River system and the transport of solutes into the Humboldt Sink. In years of normal to less-than-normal precipitation, solutes can accumulate in the Humboldt Sink and concentrate by evapotranspiration processes.

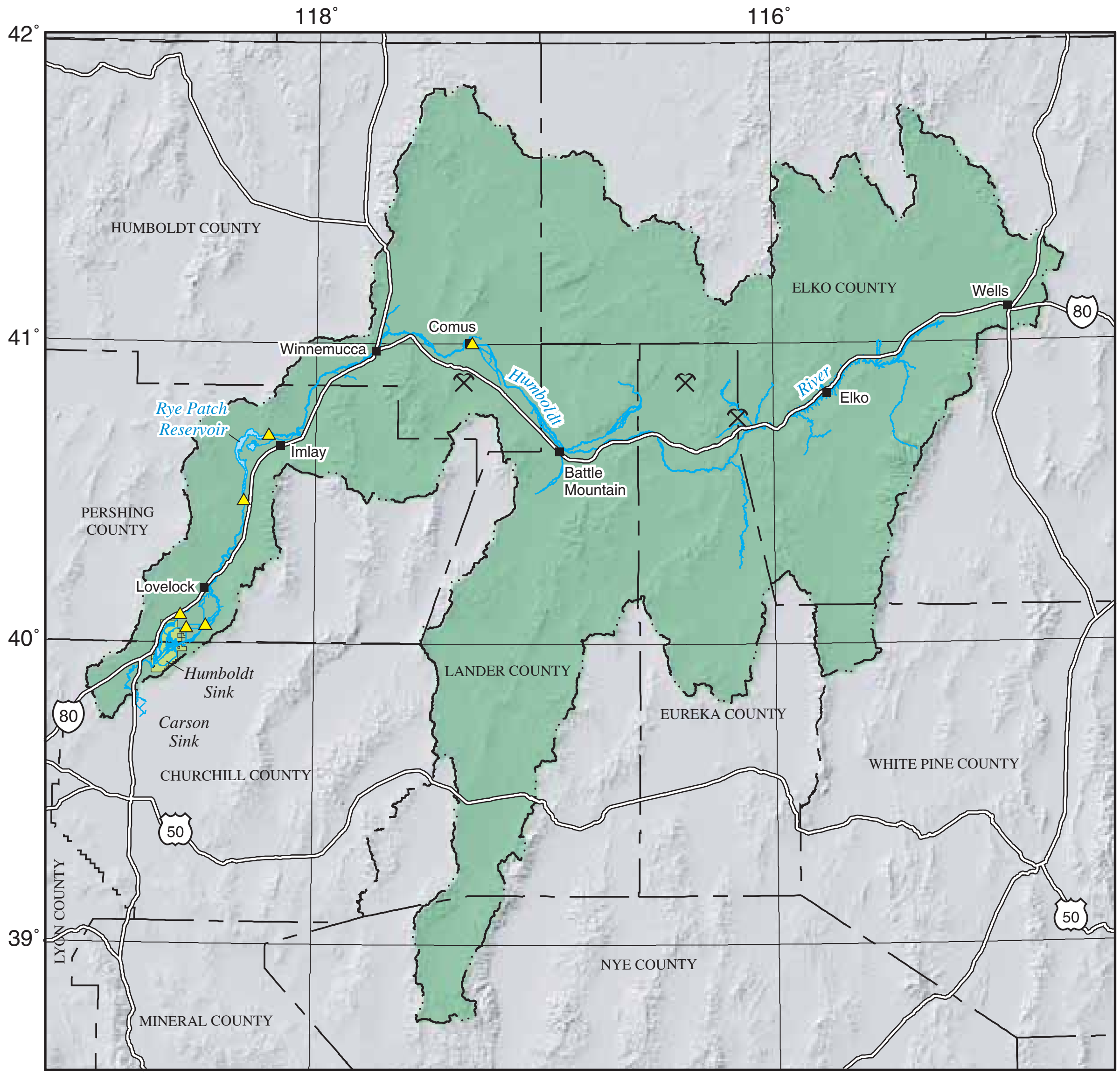
Beginning in 1990, dewatering operations at open-pit gold mines began discharging pumpage into the Humboldt River upstream from Comus (fig. 1). Initially, less than 2,000 acre-feet per year (acre-ft/yr) were discharged, but by 1998, discharges had increased to more than 110,000 acre-ft/yr (Kim Groenwald, Nevada Division of Water Resources, written commun., 2000). Concern has been expressed that inflow from the dewatering operations would increase concentrations and loads of dissolved constituents transported by the river – including constituents of concern at the HWMA (see below).

During this study, river discharge in excess of the long-term average had increased inflow to the Humboldt Sink, changing what normally is the terminus of the Humboldt River to a flow-through system that discharged to the Carson Sink until about August 1999.

The study discussed herein was a result of earlier investigations which identified concentrations of dissolved solids, arsenic, boron, mercury, molybdenum, selenium, and uranium as near or at concentrations where ecological effects may occur (Hoffman and others, 1990; Rowe and others, 1991; Seiler and others, 1993; Seiler and Tuttle, 1997).

Purpose and Scope

The purposes of this non-interpretive report are to summarize data on streamflow and quality of surface water and bottom sediment collected in the lower Humboldt River, selected drains, and Upper Humboldt Lake wetland area from May 1998 through July 2000; calculate instantaneous loads of major ions, nutrients, and trace elements of concern; and evaluate the discharge from an unnamed agricultural drain. Comparisons of the quality of surface water and of bottom sediments were made among samples collected at selected sampling sites in the study area (figs. 2 and 3; table 1). Data are compared to Federal and State standards, to criteria for protection of aquatic ecosystems, and to concentrations identified to cause concern for and effects on aquatic organisms and wildlife.



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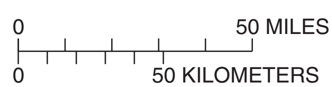

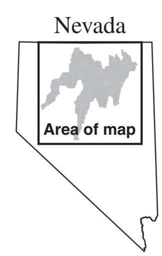

EXPLANATION

Hydrographic boundary of Humboldt River Basin

Gaging station discussed in this report

Mine dewatering operation

Humboldt Wildlife Management Area

Figure 1. Location of the Humboldt River Basin, selected U.S. Geological Survey stream gaging stations, Humboldt Wildlife Management Area, and mine-dewatering operations permitted to discharge into the Humboldt River.

Previous Investigations

Previous investigations by Hoffman and others (1990), Rowe and others (1991), Hallock and Hallock (1993), Seiler and others (1993), and Seiler and Tuttle (1997) for the Department of the Interior (DOI) National Irrigation Water Quality Program examined samples of water, sediment, and biota collected from the lower Humboldt River, selected drains, and HWMA. Dissolved solids, arsenic, boron, mercury, and selenium were identified as at or near concentrations where effects on biota may be expected. Sediments were enriched in arsenic, mercury, molybdenum, and uranium. Previous studies identified possible sources of enrichment as irrigation, historic mining activities, hydrologic setting, and drought conditions (Seiler and others, 1993, p. 2; Seiler and Tuttle, 1997, p. 1).

Acknowledgments

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DESCRIPTION OF STUDY AREA

Location and Climate

In this report, the terms "study area" and "lower Humboldt River system" refer to the Humboldt River Basin from the U.S. Geological Survey stream gaging station near Imlay downstream to include the HWMA and ephemeral outlet from the Humboldt Sink (fig. 2). The area is within the Imlay, Lovelock Valley, and White Plains hydrographic areas (Rush, 1968, map) and is bounded by the Trinity and Antelope Ranges to the west, the Eugene Mountains to the north, the East Range to the east, and the Humboldt Range to the southeast.[1] The White Plains hydrographic area is about 164 mi^2 and receives ephemeral outflow from Humboldt Lake. This area has been arbitrarily defined because no topographic divide exists between this area and the adjacent Carson Sink hydrographic area (Rush, 1968, p. 8). The Lovelock Valley hydrographic area extends upstream from the Humboldt Dike near the southern shore of Humboldt Lake to the dam at Rye Patch Reservoir, covering an area of about 740 mi^2 (Everett and Rush, 1965, p. 3). The HWMA is in the Lovelock Valley hydrographic area, about 70 mi northeast of Reno, and straddles the Pershing and Churchill County line (figs. 1 through 3). The HWMA covers approximately 57 mi^2 including Toulon and Humboldt Lakes, most of the Humboldt Sink, and the wetlands associated with the Humboldt River and agricultural drains (Seiler and others, 1993, p. 8) (fig. 3). The town of Lovelock, located about 10 mi northeast of the HWMA, is the seat of Pershing County and the largest town in the area. The Imlay hydrographic area (fig. 2) includes Rye Patch Reservoir and extends upstream from Rye Patch Dam about 35 mi to the Pershing County line, encompassing about 750 mi^2 (Rush, 1968, p. 29, plate 1, Eakin, 1962, p. 3-4).

The climate of most of the study area is arid, midlatitude desert with hot summers and cold winters (Eakin, 1962, p. 4). At Rye Patch Dam, the monthly mean minimum temperature for January, normalized for 1961-90, was 16.9 ^{o}F and the monthly mean maximum for July was 94.1 ^{o}F. Annual precipitation, normalized for the same period, was 8.22 in. and ranged from 3.82 inches in 1986 to 16.23 inches in 1983 (National Climatic Data Center, 2000). In general, surrounding mountain ranges receive more precipitation due to orographic influences: East Range, 8-15 in.; Humboldt Range, 8-25 in.; and Trinity Range and Eugene Mountains 7-17 in. (Nevada Department of Conservation and Natural Resources and U.S. Department of Agriculture, 1965, p. 20). Potential evaporation

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[1] Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960's (Rush, 1968; Cardinalli and others, 1968) for scientific and administrative purposes. The official hydrographic-area names, numbers, and geographic boundaries continue to be used in U.S. Geological Survey scientific reports and Division of Water Resources administrative activities.

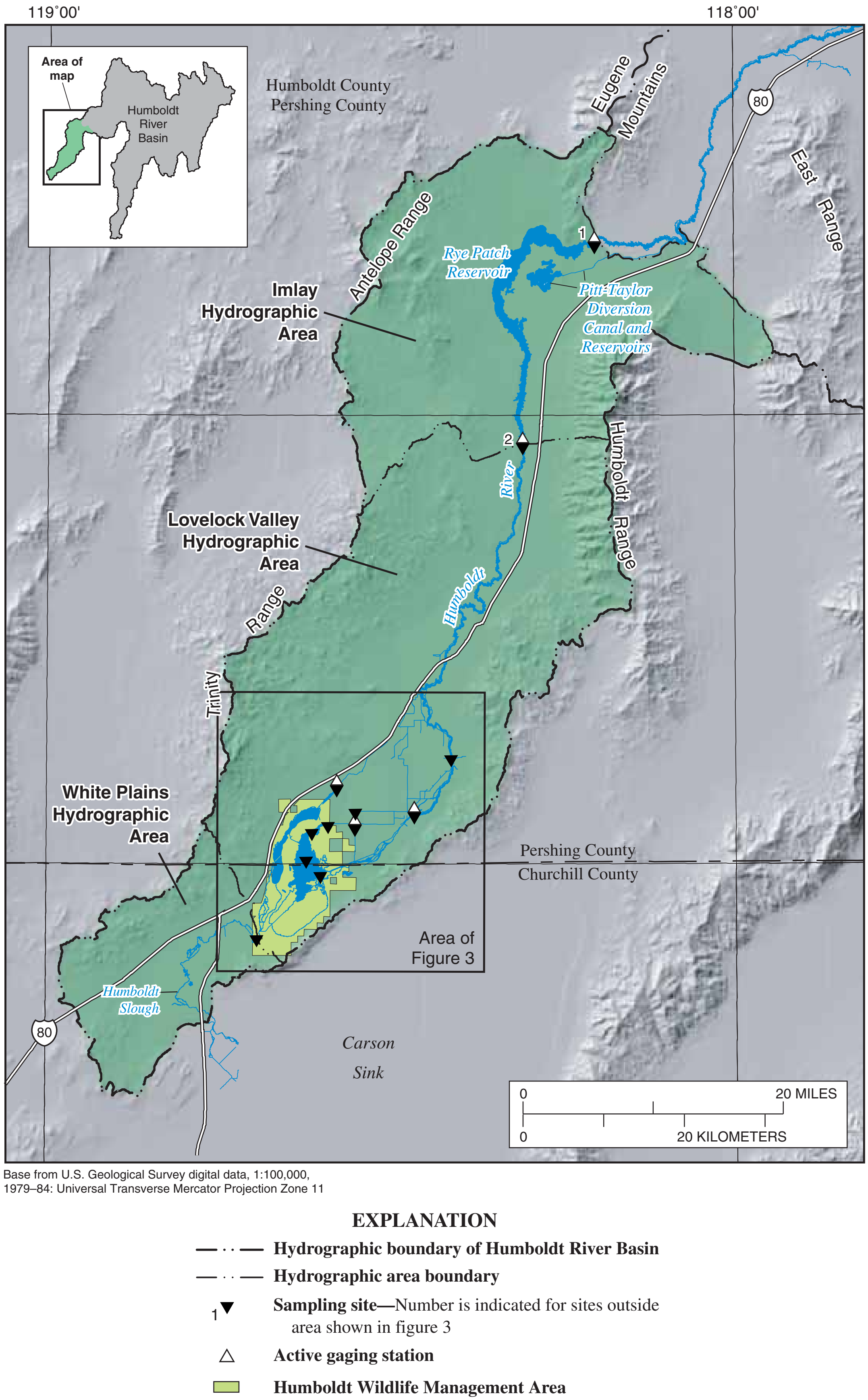

Figure 2. Site locations in the Humboldt River Basin for collection of streamflow and surface-water and bottom-sediment quality samples, 1998-2000.

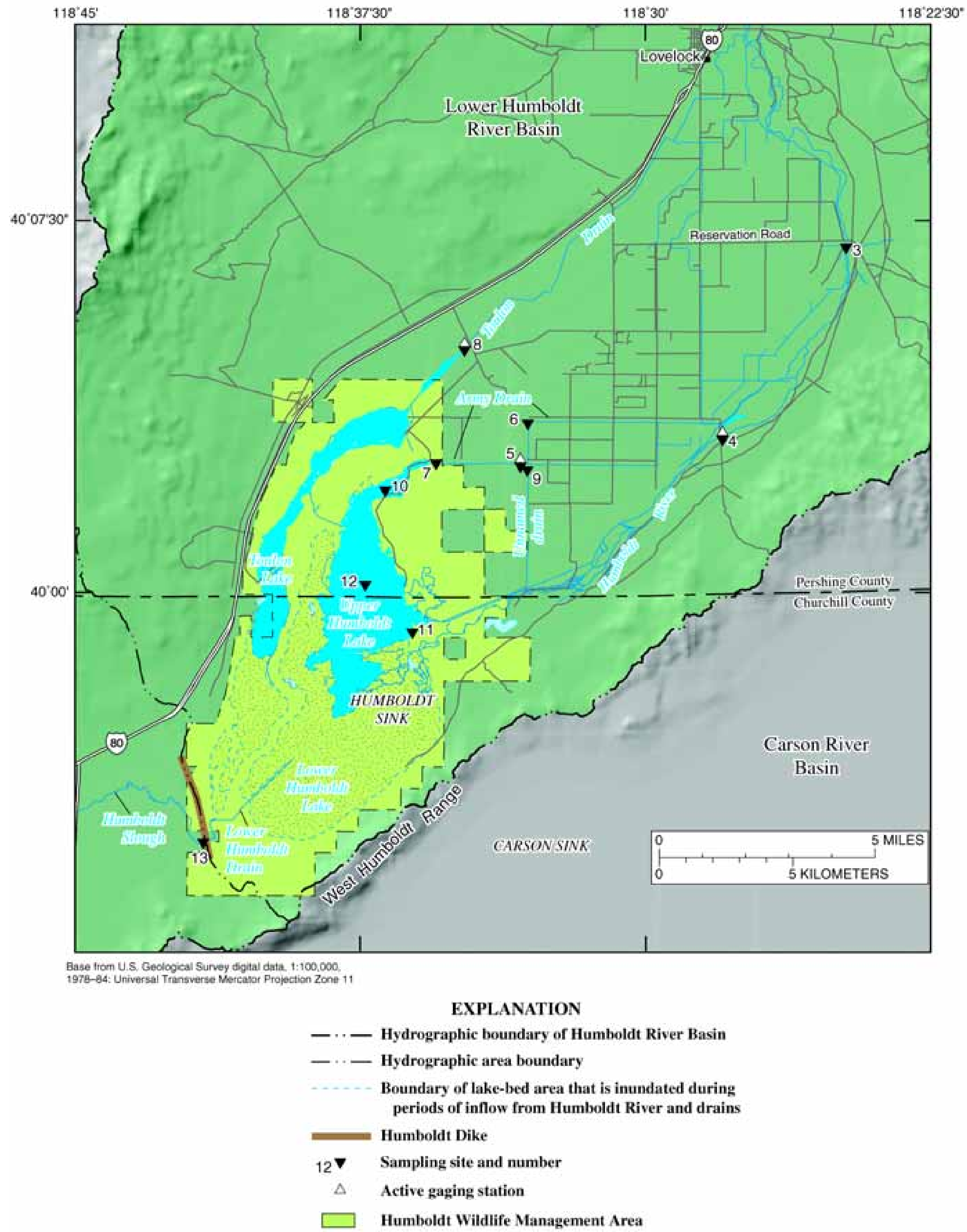

Figure 3. Site locations in the lower Humboldt River Basin downstream from Lovelock for the collection of streamflow and surface-water and bottom-sediment quality samples, 1998-2000.

Table 1. Selected sites for the collection of water and bottom-sediment samples in the lower Humboldt River Basin, 1998-2000

Site (figs. 2 and 3)	Site name (and types of data collected [1])	U.S. Geological Survey site identification [2]	Rationale for site selection
1	Humboldt River near Imlay (DWS)	10333000	Input into Rye Patch Reservoir. Integrated effects of land use in upper Humboldt River Basin (principally natural flow, mine-dewatering, and agriculture)
2	Humboldt River near Rye Patch (DWS)	10335000	Initial irrigation input to Lovelock agricultural area after storage in Rye Patch Reservoir. Effects of evapotranspiration and exposure to lake-bed sediments
3	Humboldt River at Reservation Road near Lovelock (W)	400658118244201	Low dissolved-solids inflow to Humboldt Lake; contains Rye Patch spill water and some irrigation drain water
4	Humboldt River near Lovelock (DWS)	10336000	
5	Army Drain above Iron Bridge near Lovelock (DWS)	10336039	High dissolved-solids inflow to Humboldt Lake, principally contains irrigation water
6	Army Drain at Derby Road near Toulon Lake (W)	400325118330401	
7	Army Drain at Iron Bridge near Toulon (WS)	10336040	
8	Toulon Drain at Derby Field Road (DWS)	10336035	High dissolved-solids inflow to Toulon Lake, principally contains irrigation water and treated sewage effluent
9	Unnamed drain east of Army Drain (WS)	400229118330501	High dissolved-solids inflow to Humboldt Lake via Army Drain
10	Upper Humboldt Lake at mouth of Army Drain near Toulon (WS)	10336042	Terminal drainage, wildlife concerns, bird nesting
11	Upper Humboldt Lake sample point near mouth of river (WS)	395912118360601	
12	Upper Humboldt Lake near center (S)	400009118372001	
13	Lower Humboldt Drain below Humboldt Dike near Lovelock (WS)	10336045	Ephemeral outflow from Humboldt Lake

[1] D, continuous record of discharge at active gaging station; W, water quality; S, bottom-sediment quality.

[2] U.S. Geological Survey site identification numbers were assigned according to procedures outlined in Jones and others, 1999, p. 17-18.

is 57 in. per year, estimated from Class A pan data at Rye Patch Dam (Nevada Department of Conservation and Natural Resources and U.S. Department of Agriculture, 1965, p. 21). Kohler and others (1959) estimated an evapotranspiration rate in the vicinity of the Humboldt Sink at approximately 53 in. per year.

Hydrologic Setting

The Humboldt River is the longest river (about 300 mi; Horton, 2000, p. 1-7) entirely within the State of Nevada (fig. 1) and has a drainage area of about 16,800 mi^2 (Crompton, 1995, sheet 1). The study area occupies about 1,100 mi^2, encompassing the distal seven percent of the Humboldt River Basin. Figure 4 is a schematic diagram of the flow system, showing active U.S. Geological Survey gaging stations and various water uses within the study area (modified from Jones and others, 1999, p. 321) and table 2 summarizes drainage area and annual mean discharge at the stations near Imlay and Rye Patch.

Peak flows in the Humboldt River typically result from snowmelt runoff in late winter, spring, and early summer. Flooding is infrequent but may happen in response to a warm winter storm or to rain falling on existing snowpack. After snowmelt runoff, streamflow diminishes to low flow in the middle to late summer and fall. Some reaches of the Humboldt River are lower than the adjacent water table and have ground water-sustained baseflow. Other reaches lose flow to ground water because the water table is lower than the surface of the river. In years of low precipitation, some reaches of the Humboldt River have had very little or no flow.

In the spring of 1998, Rye Patch Reservoir reached its maximum recorded capacity since its completion in 1936 (200,400 acre-ft on June 9, 1998; Preissler and others, 1999, p. 229). Monthly mean discharge recorded at the gaging station near Rye Patch exceeded 500 ft^3/s from February through August 1998 with 2,105 ft^3/s recorded as the mean for the month of June 1998. A total of about 515,000 acre-ft of water was released from Rye Patch Reservoir in water year 1998. Much of this flow discharged directly into the HWMA.

The largest water withdrawals within the Humboldt River Basin are for irrigation, mining, public supply, and electric power generation (Crompton, 1995, sheet 1). In 1995, about 650,000 acre-ft of water was withdrawn within the Humboldt River Basin with

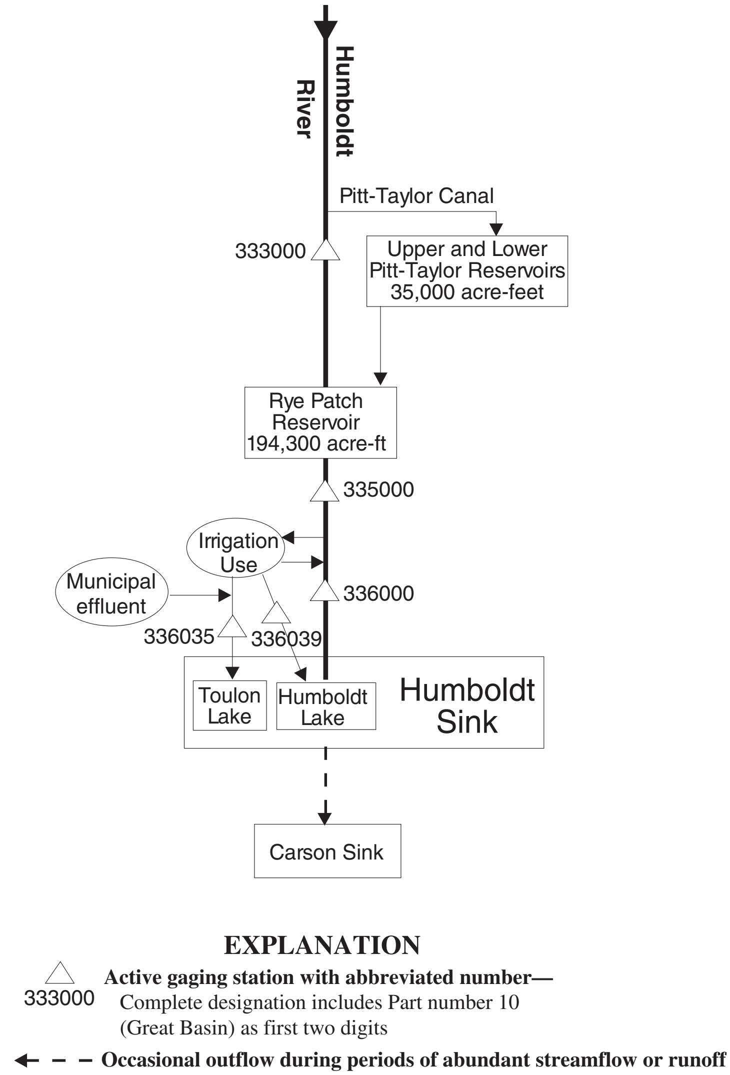

Figure 4. Schematic diagram showing the flow system, stream-gaging stations, and various water uses within the study area.

about 60 percent supplied from surface-water sources and 40 percent from ground-water sources. The 4,700 mi^2 of drainage area downstream from the gaging station at Comus had an estimated total water withdrawal of 195,000 acre-ft/yr (30 percent of the basin total). About 95 percent of the total water was withdrawn for agricultural use; public supply and mining accounted for 3 and 2 percent, respectively (E. James Crompton, U.S. Geological Survey, written commun., 1999).

In the study area, flow in the Humboldt River below Rye Patch Reservoir is regulated by reservoir operations. In years of higher than normal streamflow, reservoir water has backed upstream to the gaging station near Imlay. In normal years, about 10,000

Table 2. Drainage areas and long-term annual mean discharge, for selected U.S. Geological Survey gaging stations, Humboldt River Basin.

[Abbreviations: mi^2, square miles; ft^3/s, cubic feet per second]

Station name (period of record)	Station number	Drainage area (mi^2) [1]	Annual mean discharge (ft^3/s) [1]
Humboldt River near Imlay (water years 1935 – 2000)	10333000	15,504	285
Humboldt River near Rye Patch (water years 1936 – 2000)	10335000	16,002	256

[1] Data from Allander and others (2001, p 224 and 230).

acre-ft/yr of water is diverted from the river to the Pitt-Taylor Canal above Imlay for storage in the Pitt-Taylor Reservoirs to supplement agricultural storage in Rye Patch Reservoir (Rush and Rice, 1972). Normal reservoir operations will store streamflow during periods when irrigation is not required and release flow according to needs of irrigators holding water rights. Because releases from Rye Patch Reservoir are for irrigation, most flow in the Humboldt River is diverted to agricultural fields upstream from the gaging station near Lovelock, and flows to the HWMA via the Humboldt River usually are small.

Nearly 50 mi of main canals convey irrigation water to the agricultural fields, and about 100 mi of lateral connecting drains and 130 mi of open return drains are maintained in the agricultural area downstream from Rye Patch Dam (Seiler and others, 1993, p. 10). Agricultural drains in the study area are designed to maintain the water table below the root zone by receiving deep-percolation water applied to crops. Drain flow is controlled by applications of irrigation water and the depth of the water table relative to the bottom of the drain channel. In addition to normal collection of irrigation return flow, Army Drain receives pumpage from an unnamed drain (fig. 3) and Toulon Drain receives treated effluent from the municipal wastewater treatment plant in Lovelock.

The HWMA receives inflow from the Humboldt River that is slightly influenced by irrigation drainage, and inflow from agricultural drains that includes both irrigation return flow and treated municipal effluent. In normal years, the amount of water lost to evapotranspiration will exceed the amounts supplied to the HWMA by the river and drains. In wet years, such as 1983-84 and 1997-98, the Humboldt Sink overflows into the Lower Humboldt Drain, which discharges to the Carson Sink by way of the Humboldt Slough. The Lower Humboldt Drain was dredged during the 1940's to allow more water to leave the Humboldt Sink to protect agricultural fields from flooding (Seiler and others, 1993, p. 11). Topographic and photographic evidence indicates that the maximum water-surface altitude of the Humboldt Sink during overflow is near 3,900 ft, which is equivalent to a lake area of about 56 mi^2. The estimated volume of lake water at 3,900 ft is approximately 300,000 acre-ft, assuming a lake-bottom low point at about 3,885 ft, a lake area of about 26 mi^2 at 3,890 ft, a simplistic circular perimeter, and spherical-segment geometry (A.S. VanDenburgh and Michael S. Lico, U.S. Geological Survey, written commun., 2001).

CONTAMINANT CRITERIA

Surface water discharges are allowed to contain contaminants below concentrations that have been found to be harmful to human health, aquatic biota, wildlife, livestock and, where applicable, below concentrations making water unsuitable for irrigation. Tables 3 and 4 summarize water-quality and sediment standards and criteria used by the State of Nevada, the U.S. Environmental Protection Agency (USEPA), and others. Where water-quality criteria were unavailable, comparison of data from this study was made with information gathered from the scientific literature.

STUDY APPROACH AND METHODS

Data collected for this study include continual records of stage, temperature, and specific conductance at five U.S. Geological Survey stream gaging stations, and instantaneous measurements of streamflow, temperature, specific conductance, pH, and dissolved oxygen at sites of surface-water sample collection. From June 1998 to September 1999, surface-water samples were collected about every six weeks and bottom-sediment samples annually from the five gaging stations, from an unnamed drain east of Army Drain, and from Lower Humboldt Drain (the ephemeral outlet of the HWMA). From August 1999 to July 2000, surface-water samples were collected at two locations and bottom sediment from three locations within the HWMA.

Additional streamflow data for Army Drain was collected from September 1999 to September 2000. Locations of these sites are shown on figures 2 and 3 and described in table 1.

At gaging stations, daily mean streamflow was computed using stage-discharge relations (Kennedy, 1984; Preissler and others, 1999; Jones and others, 1999). Following methods outlined by Rantz and others (1982), instantaneous discharge measurements were made at all sampling locations except at the Humboldt River near Imlay and near Rye Patch, where computed discharge values were reported and used in mass-transport calculations.

Flow from an unnamed agricultural drain into Army Drain was evaluated using measurements of stage and specific conductance made every 15 minutes at the gage installed on Army Drain in April 1999 approximately 30 feet downstream from the unnamed drain culvert. A rating (stage-discharge relation) was defined by discharge measurements at the gaging station, and flow computed at 15-minute intervals. The lift pump that delivers agricultural drainage from the unnamed drain into Army Drain malfunctioned in April 1999 and was out of service until the end of May 1999. Therefore, only data from June 1999 through September 2000 were used. To estimate discharge from the unnamed drain, Army Drain flow data were separated into two groups: "pump on" and "pump off." The onset of pumping was defined by a dramatic increase (assumed to be greater than 3 ft^3/s) in flow during a 15-minute time period and was considered to continue until a similar decrease in flow occurred. All other data were assumed to represent "pump-off" conditions. The selection of 3 ft^3/s was considered sensitive enough to distinguish the onset of pumping from natural fluctuations in drain flow. The pump was assumed to be on for the entire sequence of 15-minute time periods. To estimate the monthly discharges from the unnamed drain, monthly median "pump-off" values were subtracted from respective monthly median "pump-on" values.

The total volume of irrigation drainage within Army Drain below the unnamed drain ranged from 406 to 3,880 acre-ft/mo from June 1999 through September 2000 (Jones and others, 1999, p. 377; Allander and others, 2001, p. 245). The approximate volumes of pumpage from the unnamed drain into Army Drain were estimated by multiplying the period during which the pump was operating by the estimated discharge value.

Surface-water samples were collected and processed using procedures described by Shelton (1994). The equal-discharge-increment sampling technique was used to collect samples from the Humboldt River near Lovelock, Army Drain, and Lower Humboldt Drain. The equal-width-increment sampling technique was used for the Humboldt River near Imlay and Humboldt River near Rye Patch. A single vertical collection technique was used at the centroid of flow at the culvert on Toulon Drain and a single fixed-intake was used for the unnamed drain and wetland sites. For quality assurance, a duplicate surface-water sample was collected in August 1998 from the Humboldt River near Rye Patch Reservoir. Field blanks were processed at one randomly selected site during each field trip (except August and September 1998) to determine potential contamination due to sampling equipment or processing procedures. Field blanks were processed using inorganic-blank water certified by the U.S. Geological Survey National Water Quality Laboratory (NWQL). All samples, except those for low-level mercury determinations, and field blanks were sent on ice to the NWQL for analyses (table 5).

The NWQL reporting level (LRL) generally is twice the long-term method detection level (LT-MDL) that is derived from the standard deviation of a minimum of 24 MDL spike-sample measurements over an extended period of time. A MDL is determined by analyzing a sample in a given matrix containing the analyte and is the minimum analyte concentration that can be measured and reported within 99-percent confidence that the analyte concentration is greater than zero. The risk of falsely reporting a concentration at or greater than the LT-MDL is predicted to be less than or equal to one percent (Childress and others, 1999, p. 19).

Samples of bottom sediment were collected from the Humboldt River near Imlay, Rye Patch, and Lovelock, and from Toulon and Army Drains, the unnamed drain, and Lower Humboldt Drain. At each of these sites, sediments were collected from the top 1-2 in. from several adjacent depositional areas using a polypropylene spatula, wet sieved in the field through 62-μm nylon mesh using native water, and composited into and homogenized in a glass bowl (Shelton and Capel, 1994). Wetland sediments also were collected using a polyvinyl chloride (PVC) corer. Samples were placed into plastic bags, homogenized, and sieved, and then processed in the same manner as the other sediments. All composited sediments were transferred to

Table 3. Selected effect concentrations and U.S. Environmental Protection Agency (USEPA) and Nevada Division of Environmental Protection (NDEP) water-quality criteria for inorganic substances

[Source of data indicated by superscript with citation(s) following table. Abbreviations: mg/L, milligrams per liter; μg/L micrograms per liter; hr, hour; H_2S, hydrogen sulfide; μmhos/cm, micro-ohms per centimeter]

Constituent [2]	Maximum concentration recommended for different beneficial uses[1] (μg/L, except as noted)				
	Municipal or domestic supply	Aquatic life	Ecological-effect concentration [3]	Watering of livestock	Irrigation
Sodium			1,500 mg/L[4]		
Sulfide (as H_2S)		2[5]			
Chloride					
CMC		860 mg/L[6]			
CCC		230 mg/L[6]			
Fluoride				2,000[7]	1,000[7]
Dissolved Solids	500/1,000 mg/L[7,8]		4,900 mg/L [9]	3,000 mg/L [7]	
Un-ionized ammonia (as nitrogen)		0.02 mg/L [7,10]			
Aluminum			120 [11]		
CMC		750 [6,12]			
CCC		87 [6,12]			
Antimony	146 [5]		610 [5,13]		
Arsenic, total	50[7]		48 [5,14] 40 [14]	200[7]	100[7]
Arsenic (III)					
CMC		340 [6,16,7]			
CCC		150 [6,16,7]			
Barium	2,000[7]				
Boron		(18)	200 [19]	5,000[7]	750 [5]
Chromium, total	100[7]			1,000[7]	100[7]
Chromium (III)			44 [20]		
CMC		2,131 to 13,277 [21,17]			
CCC		254 to 1,583 [21,17]			
Chromium (VI)			16 to 21 [22]		
CMC		16 [23]			
CCC		11 [23]			
Copper				500[7]	200[7]
CMC		23 to 189 [21,17]			
CCC		15 to 99 [21,17]			
Iron		1,000 [5]			5,000[7]
Manganese					200[7]
Mercury	2[7]	2[7] 0.012[7]	0.23 [5] 0.2 [15] 0.26 [24] 0.03 [25] 0.1 [26]	10[7]	
CMC		1.4 [27,17]			
CCC		0.77 [27,17]			
Molybdenum		19[7]	10,000 [28]		

Table 3. Selected effect concentrations and U.S. Environmental Protection Agency (USEPA) and Nevada Division of Environmental Protection (NDEP) water-quality criteria for inorganic substances--Continued

Constituent [2]	Maximum concentration recommended for different beneficial uses[1] (μg/L, except as noted)				
	Municipal or domestic supply	Aquatic life	Ecological-effect concentration [3]	Watering of livestock	Irrigation
Nickel	13.4[7]		11.7 to 125 [29]		200[7]
CMC		1,761 to 11,658 [21]			
CCC		196 to 1,296 [21]			
Selenium	50[7]	20[7] 5.0[7]	2 to 5 [30]	50[7]	20[7]
Zinc				25,000[7]	2,000[7]
CMC		145 to 965[21]			
CCC		132 to 874[21]			
Uranium	30 [31]				

[1] Criteria listed in this table apply to concentrations within the water column.

[2] The Criteria Maximum Concentration (CMC) value is an estimation of the highest surface-water concentration an aquatic community can be briefly exposed to without exhibiting an ill effect. The Criterion Continuous Concentration (CCC) is an estimated maximum concentration of a substance in surface water to which aquatic communities may be continuously exposed without detrimental effect (USEPA, 1999, p. 21).

[3] Although ecological-effect concentrations are not recognized by the State of Nevada as a beneficial use (Randy Pahl, NDEP, written commun., 2003), these values are included in this table for comparative purposes.

[4] Mitcham and Wobeser (1988a, p. 41).

[5] USEPA, 1986.

[6] These criteria were obtained from http://www.epa.gov/fedrgstr/EPA-WATER/1998/December/Day-10/w30272.htm accessed on December 13, 1999.

[7] From the Nevada Bureau of Water Quality Planning (1998, p. 445A-46 through 445A-70).

[8] 1,000 mg/L is the accepted maximum-contaminant standard (aesthetic, State enforceable); 500 mg/L is the drinking-water advisory concentration. These concentrations are not enforced within the State of Nevada but are included in the regulations for informational purposes only (Randy Pahl, Nevada Bureau of Water Quality and Planning, written commun., 2003); water-quality standards for dissolved solids along specific reaches of the Humboldt River (NDEP, 1998) are as follows: Imlay to Woolsey, 1,000 mg/L (p. 445A-138); Woolsey to Rodgers Dam, 500 mg/L (p. 445A-62); and downstream from Rodgers Dam, no standard (p. 445A-64 and 65).

[9] Value based on the effect level of 7,500 μmhos/cm (Mitcham and Wobeser, 1988b, p. 49); effect concentration was converted to mg/L dissolved solids using the linear relationship: dissolved solids (mg/L) = (0.6644)(specific conductance) – 110.65, (R^2=0.9899), that was derived using data collected as part of this study.

[10] The Nevada Bureau of Water Quality Planning (1998, p. 137-138) shows <0.02 mg/L to be protective of the beneficial use for warm-water fishery control points at Imlay and Woolsey.

[11] Reduced uptake of calcium by the crayfish, *Orconected virilis*, at pH 5.5 (Sparling and Lowe, 1996, p. 26).

[12] Value based on pH range of 6.5 – 9.0.

[13] Value was determined for freshwater algae (species not specified); acute and chronic toxicity to freshwater aquatic life were determined to be 9,000 and 1,600 μg/L of antimony, respectively (USEPA, 1986).

[14] This value based on arsenate, As(V), for freshwater aquatic plants (USEPA, 1986).

[15] Birge and others (1978, p. 98-99); value in table is from toxicity data obtained for embryo and larval rainbow trout. Mercury effect concentration as mercuric chloride.

[16] These criteria assume that As(III) and As(V) elicit similar toxicities and therefore have additive toxicity. However, as noted in the criteria document (website, in footnote b) data are insufficient to support these assumptions.

[17] Based on the ability of an impacted system to recover within three years (on average) after a one-time exceedence of the criteria.

[18] The aquatic-life criterion for boron (550 μg/L) was eliminated by the Nevada Bureau of Health Protection Services in October 1995 (Thodal and Tuttle, 1996, p.16).

[19] Birge and Black (1977, p. 27).

[20] Reduced fecundity in *Daphnia magna* (Eisler, 2000a, p.68).

[21] Values are adjusted for the median hardness values (157 – 1,462 mg/L as calcium carbonate) found in the system during the study period (05/98 through 07/00). Equations used to calculate these criteria can be obtained from the Nevada Bureau of Water Quality Planning and are currently in use by NDEP (Adele Basham, NDEP, oral commun., 2000).

[22] Reduced growth rate in rainbow trout and Chinook salmon fingerlings with exposure for 14 to 16 weeks (Eisler, 2000a, p. 68).

[23] USEPA (2002, p. 12).

Table 3.--Continued.

[24] Snarski and Olson (1982, p. 152). Mercuric chloride was used during the toxicity assays.
[25] Reproduction inhibited in the planaria, *Dugesia dorotocephala*, when exposed to methylmercury (Eisler, 2000b, p. 375).
[26] Reduced hatching success of zebrafish when exposed to inorganic mercury (Eisler, 2000b, p. 375).
[27] EPA criteria are with respect to mercury(II). Mercury(II) data were used to extrapolate to total mercury. These criteria do not consider methyl-mercury concentrations (website, in footnote b). During the study period, the acute and chronic criteria adopted by the State of Nevada were 2 and 0.012 µg/L (Nevada Bureau of Water Quality Planning, 1998, p. 445A-50).
[28] At pH 6.6 (Seiler, 1975. p. 25).
[29] Eisler (2000c, p. 457).
[30] Lemly and Smith (1987, p. 9).
[31] USEPA, 2000, p. 76712.

Table 4. Summary of Canadian Interim Freshwater Sediment-Quality Guidelines for the protection of aquatic life (Canadian Council of Ministers of the Environment, 1999), Department of the Interior (1998) and consensus-based sediment-effect concentrations.

[Abbreviations: ISQG, Canadian Interim Sediment-Quality Guidelines; PEL, probable-effect level; TEC, threshold-effect concentration; --, value not available]

Constituent (all concentrations in micrograms per gram)	ISQG [1]	PEL [1]	TEC [2]	No-effect concentration [3]
Arsenic	5.9	17.0	9.79	8.2
Cadmium	0.6	3.5	0.99	--
Chromium	37.3	90	43.4	--
Copper	35.7	197	31.6	--
Lead	35	91.3	35.8	--
Mercury	0.17	0.486	0.18	0.065
Nickel	--	48.6 [2]	22.7	--
Selenium	--	--	4 [4]	1
Zinc	123	315	121	--

[1] From the Canadian Council of Ministers of the Environment (1999).
[2] From MacDonald and others (2000, p. 23-24).
[3] From the Department of the Interior (1998).
[4] Ecological-effect concentration for fish and waterfowl (Lemly and Smith, 1987, p. 9, table 2).

Table 5. National Water Quality Laboratory and field reporting limits for constituents in water and bottom-sediment samples collected in 1998 through 2000.

[Abbreviations and symbol: mg/L, milligrams per liter; µg/L, micrograms per liter; ng/L, nanograms per liter; ng/g, nanograms per gram; µg/g, micrograms per gram; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, not determined]

Constituent	Water	Bottom sediment (dry weight)
Alkalinity (as $CaCO_3$)	5 mg/L	--
pH	0.1 standard unit	--
Specific Conductance	5 µS/cm	--
Dissolved Oxygen	0.1 mg/L	--
Aluminum	1 µg/L	0.005 percent
Antimony	1 µg/L	0.1 µg/g
Arsenic	2 µg/L	0.1 µg/g
Barium	1 µg/L	1 µg/g
Beryllium	1 µg/L	0.1 µg/g
Bismuth	--	1 µg/g
Boron	16 µg/L	--
Cadmium	1 µg/L	0.1 µg/g
Calcium	0.02 mg/L	0.005 percent
Carbon (total)	--	0.01 percent
Carbon (inorganic)	--	0.01 percent
Carbon (organic)	--	0.01 percent
Cerium	--	1 µg/g
Chloride	0.29 mg/L	--
Chromium	1 µg/L	1 µg/g
Cobalt	1 µg/L	1 µg/g
Copper	1 µg/L	1 µg/g
Dissolved Solids	10 mg/L	--
Europium	--	1 µg/g
Fluoride	0.1 mg/L	--
Gallium	--	1 µg/g
Gold	--	1 µg/g
Holmium	--	1 µg/g
Iron	10 µg/L	0.005 percent
Lanthanum	--	1 µg/g
Lead	1 µg/L	1 µg/g
Lithium	--	1 µg/g
Magnesium	0.014 mg/L	0.005 percent
Manganese	1 µg/L	4 µg/g
Mercury (standard)	0.1 µg/L	0.02 µg/g
Mercury (low-level analysis)	0.01 ng/L	0.1 ng/g
Methyl Mercury (low-level analysis)	0.01 ng/L	0.1 ng/g

Table 5. National Water Quality Laboratory and field reporting limits for constituents in water and bottom-sediment samples collected in 1998 through 2000--Continued

Constituent	Water	Bottom sediment (dry weight)
Molybdenum	1 µg/L	0.5 µg/g
Neodymium	--	1 µg/g
Nickel	1 µg/L	2 µg/g
Niobium	--	4 µg/g
Nitrogen (ammonia)	0.02 mg/L	--
Nitrogen (ammonia + organic), total	0.1 mg/L	--
Nitrogen (ammonia + organic), filtered	0.1 mg/L	--
Nitrogen (nitrite + nitrate), filtered	0.05 mg/L	--
Nitrogen (nitrite), filtered	0.01 mg/L	--
Phosphorus (total)	0.008 mg/L	0.005 percent
Phosphorus (filtered)	0.006 mg/L	--
Phosphorus (ortho)	0.01 mg/L	--
Potassium	0.24 mg/L	0.005 percent
Scandium	--	2 µg/g
Selenium	1 and 2.4 µg/L [1]	0.1 µg/g
Silica	0.09 mg/L	--
Silver	1 µg/L	0.1 µg/g
Sodium	0.09 mg/L	0.005 percent
Strontium	--	2 µg/g
Sulfate	0.31 mg/L	--
Sulfur	--	0.05 percent
Tantalum	--	1 µg/g
Thallium	--	1 µg/g
Thorium	--	1 µg/g
Tin	--	1 µg/g
Titanium	--	0.005 percent
Uranium	1 µg/L	0.1 µg/g
Vanadium	--	2 µg/g
Ytterbium	--	1 µg/g
Yttrium	--	1 µg/g
Zinc	1 µg/L	2 µg/g

[1] Laboratory method-reporting limit changed from 1 to 2.4 µg/L in water year 2001 (Glenda Brown, NWQL, written commun., 2002).

plastic jars, kept on ice, and analyzed by the U.S. Geological Survey Geologic Division in Denver, Colo., for trace elements (table 4).

In addition to the routine samples, water- and bottom-sediment samples were collected in August 1999 for determination of low-level concentrations of total mercury and methyl mercury by the U.S. Geological Survey Mercury Research Laboratory in Madison, Wisc., using methods described in Olson and DeWild (1999) and Olson and others (1997). Aliquots of unfiltered surface water were taken from the same composite from which routine water-quality samples were taken. These aliquots were placed into acid-cleaned teflon bottles and preserved with hydrochloric acid. Unsieved bottom sediments were collected from several adjacent depositional areas and directly composited into an acid-cleaned teflon vial. Water samples and sediment were kept on dry ice and sent to the research laboratory upon returning from the field. Teflon bottles, teflon vials, and hydrochloric acid were provided by the laboratory.

RESULTS

Field Blanks

Field blanks were taken during all field trips, except those of August and September 1998, and processed in the same manner as the samples. Field-blank analysis results are listed in table 6. Constituents not listed in table 6 were below minimum laboratory reporting limits in all blanks. Concentrations of constituents detected in field blanks are within the same order of magnitude as laboratory reporting levels except calcium, chloride, aluminum, and low-level total and methyl mercury.

Humboldt River and Drains

Surface Water

Results of field measurements and inorganic chemical analyses for samples collected from the lower Humboldt River and selected drains are tabulated at the end of this report as Supplemental Data and also are listed in U.S. Geological Survey annual data reports for Nevada water years 1998 and 1999 (Preissler and others, 1999; Jones and others, 1999). Streamflow and selected surface water-quality data are statistically summarized in tables 7 through 21. Streamflow and selected water-quality constituents listed herein (tables 7 through 21; Appendix A) for the Humboldt River sampling sites near Imlay and Rye Patch, and for Toulon Drain, and Lower Humboldt Drain differ from those published in the annual water-resources data reports for 1998 and 1999 (Preissler and others, 1999, p. 500-504; Jones and others, 1999, p. 384-390). The updated discharges are based on revised correction factors (Jones and others, 1999, p. 18). The revised concentrations are based on NWQL verifications that had not been obtained at the time the data were initially published in the annual reports. The discharges and concentrations listed in tables 7 through 22 and in Appendix A are considered more accurate than the previously published provisional values.

Table 6. Constituent concentrations in field blanks during water sampling of the Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviations: mg/L, milligrams per liter; µg/L, micrograms per liter; ng/L, nanograms per liter]

Constituent [1]	Frequency of detection	Range of concentration
Calcium	4 out of 10	0.02 to 0.14 mg/L
Sodium	5 out of 10	0.06 to 0.1 mg/L
Chloride	6 out of 10	0.12 to 1.5 mg/L
Silica	3 out of 10	0.05 to 0.07 mg/L
Dissolved Solids	1 out of 10	12 mg/L
Nitrogen (nitrite and nitrate)	2 out of 10	0.06 and 0.07 mg/L
Nitrogen (ammonia)	4 out of 10	0.02 to 0.03 mg/L
Nitrogen (ammonia + organic)	1 out of 10	0.11 mg/L
Phosphorus (ortho)	2 out of 10	0.01 and 0.02 mg/L
Aluminum	4 out of 10	1.2 to 4 µg/L
Iron	1 out of 10	10 µg/L
Mercury (methyl)	1 out of 2	0.12 ng/L
Mercury (total)	2 out of 2	0.16 and 0.67 ng/L
Zinc	1 out of 10	1.1 µg/L

[1] For constituents not listed in this table, all concentrations were less than laboratory reporting levels.

Streamflow

Streamflow in 1998 and 1999 at gaging stations on the Humboldt River near Imlay and below Rye Patch Reservoir peaked in June. In June 1998, the Humboldt River sampling site near Lovelock was inaccessible due to flooding. Therefore, the discharge measurement and water-quality samples were taken above the agricultural diversions near Reservation Road (sampling site 3), upstream from the routine sampling site that was located below agricultural diversions. Streamflow measured near Reservation Road was 2,100 ft^3/s on June 24, 1998. Measured instantaneous streamflow at the routine sampling site near Lovelock (July 1998 through September 1999) ranged from 18 to 904 ft^3/s. Peak flows were measured in the river near Lovelock in June 1998 and March 1999. Measured streamflow in the Lower Humboldt Drain was 940 ft^3/s on July 20, 1998, and declined steadily to 27 ft^3/s on August 9, 1999, the final site visit. Streamflow was not measured in the unnamed drain. Discharges in Army and Toulon Drains generally were higher than measured in previous investigations (Seiler and others, 1993, p. 78; Seiler and Tuttle, 1997, p. 23). During wetland sampling on April 20 and July 21, 2000 mean streamflow in the Humboldt River near Lovelock was 66 and 44 ft^3/s, respectively and mean flow in Army Drain was 61 and 52 ft^3/s, respectively. Table 7 statistically summarizes flows measured at the sampling sites during this study.

From June 1999 through September 2000, flow in Army Drain below the unnamed drain was variable during both “pump-on” and “pump-off” periods, ranging from 9 to 111 and from 5 to 106 ft^3/s, respectively. Median flow ranged from 11 to 69 ft^3/s when the pump was on and from 7 to 62 ft^3/s when the pump was not operating (fig. 5). During the study period, the estimated discharge from the unnamed drain ranged from about 3 to 16 ft^3/s (fig. 6). Based on the estimates within this report, the volume of irrigation drainage pumped from the unnamed drain into Army Drain was relatively small, ranging from about 7 to 240 acre-ft/mo during June 1999 through September 2000 (fig. 7).

Specific Conductance

Specific conductance increased in Humboldt River water with distance downstream (table 8). Agricultural irrigation drainage waters had the highest specific conductances. A strong correlation ($R^2 = 0.9899$) exists between specific conductance and dissolved-solids concentration.

pH and Temperature

Instantaneous measurements showed that pH of the Humboldt River did not vary much from the sampling site near Imlay to that near Lovelock (8.5 ±0.1). Agricultural drain waters also had similar pH values (8.2 ±0.2). Lower Humboldt Drain water had a pH of 8.6 ±0.1.

At all sampling sites, minimum temperatures occurred in the winter and maximum temperatures occurred in the summer.

Table 7. Minimum, median, and maximum discharge in the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation and symbol: ft^3/s, cubic feet per second; --, not measured]

Sampling site	Number of discharge measurements	Discharge (ft^3/s) [1]		
		Minimum	Median	Maximum
Humboldt River near Imlay	13	45	410	2,000
Humboldt River near Rye Patch	13	140	520	2,400
Humboldt River near Lovelock	13	18	140	2,100 [2]
Army Drain	13	7	32	90
Toulon Drain	13	5	17	27
Unnamed drain	--	--	--	--
Lower Humboldt Drain	13	0	340	940

[1] Daily mean discharge values for the Humboldt River during HWMA sampling on April 20 and July 21, 2000 were 66 and 14 ft^3/s, respectively. Daily mean discharges in Army Drain on April 20 and July 21, 2000 were 61 and 52 ft^3/s, respectively. Water quality samples were not taken on these dates from the river or Army Drain.

[2] Measurement in June 1998 taken near Reservation Road.

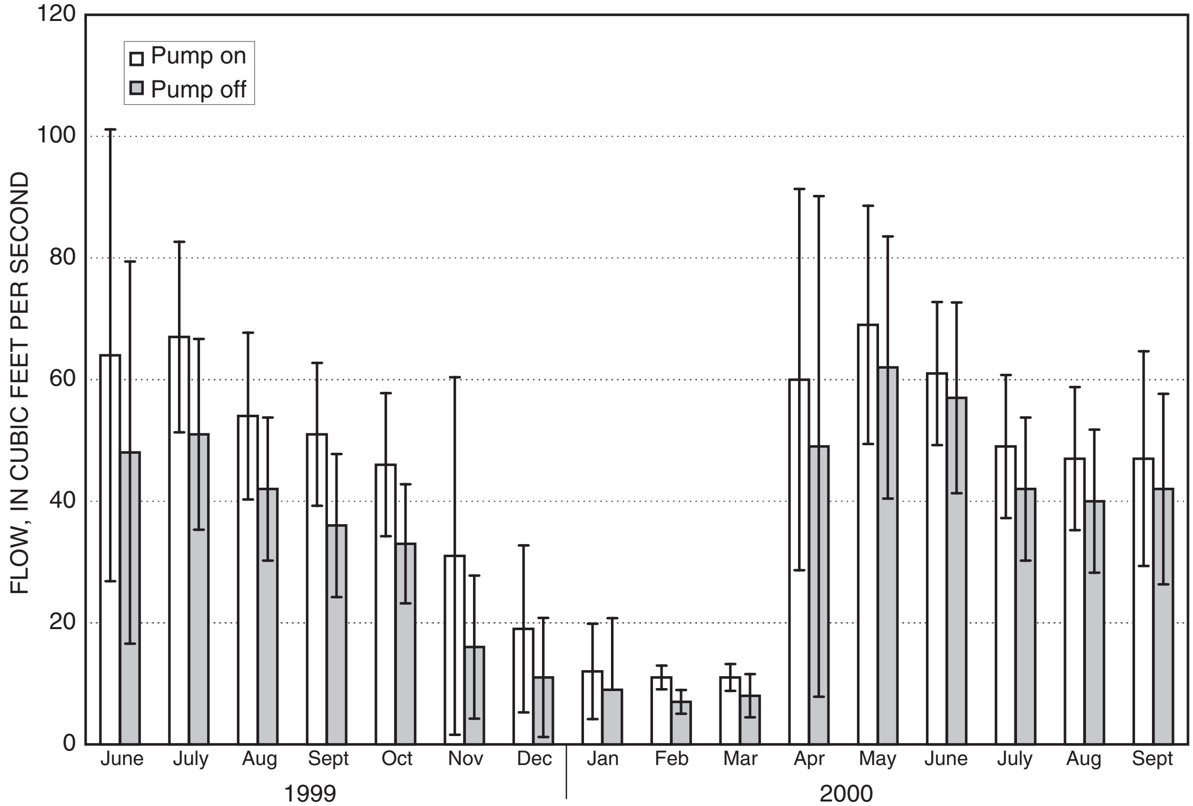

Figure 5. Graph showing median monthly discharge in Army Drain during “pump-on” and “pump-off” periods, June 1999-September 2000. Error bars are the 95-percent confidence limits.

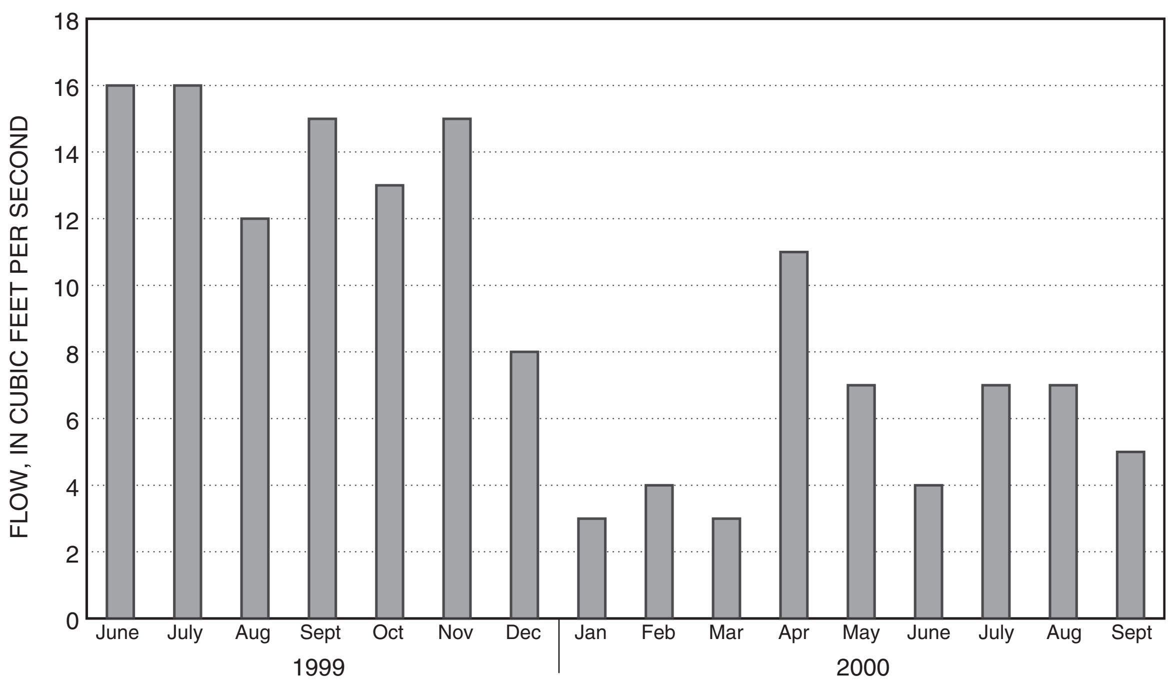

Figure 6. Graph showing estimated median monthly discharge values for the unnamed drain, June 1999-September 2000.

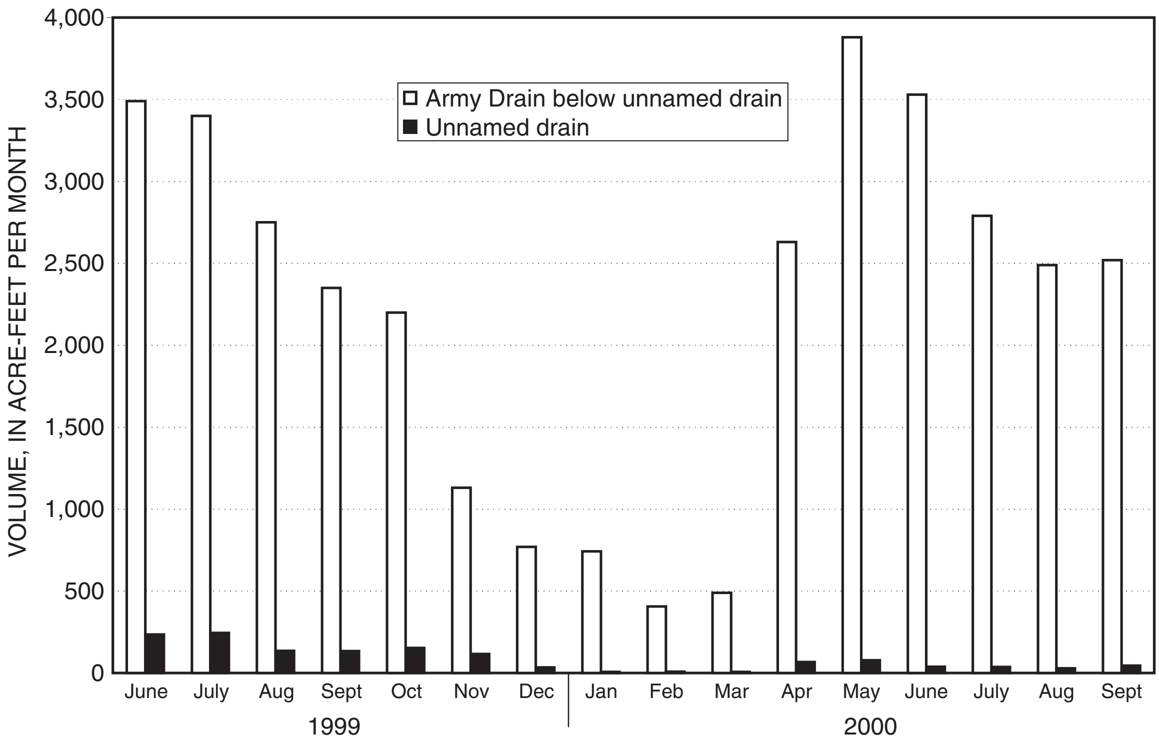

Figure 7. Graph showing estimated monthly volumes in Army Drain and the contribution from the unnamed drain, June 1999-September 2000.

Table 8. Minimum, median, and maximum specific conductance values in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Sampling site	Number of observations	Specific conductance (µS/cm)		
		Minimum	Median	Maximum
Humboldt River near Imlay	13	580	710	940
Humboldt River near Rye Patch	13	750	870	1,300
Humboldt River near Lovelock	13	790 [1]	1,200	2,300
Army Drain	13	2,800	5,100	7,000
Toulon Drain	13	2,500	3,000	4,100
Unnamed drain	7	8,500	11,200	14,600
Lower Humboldt Drain	12	1,200	2,100	5,200

[1] Measurement in June 1998 taken near Reservation Road.

Dissolved Oxygen

During this study dissolved-oxygen concentrations in the lower Humboldt River and selected drains ranged from 3.3 to 27.3 mg/L (Appendix A). Median concentrations ranged from 7.8 to 11 mg/L (table 9). Dissolved-oxygen saturation in the Humboldt River, agricultural drains, and Lower Humboldt Drain ranged from 79 to 140, 42 to 360, and 55 to 140 percent, respectively.

Sodium

In general, sodium concentrations increased with distance downstream. The highest concentrations of sodium were found in water samples collected from the agricultural drains (fig. 8, table 10). Concentrations in samples collected from the Humboldt River near Imlay and Rye Patch and from the unnamed agricultural drain were similar to those from previous investigations (Seiler and others, 1993, p. 79; Seiler and Tuttle, 1997, p. 25-26). However, sodium concentrations in samples collected from the Humboldt River near Lovelock during this study generally were lower than in samples collected by Seiler and others (1993, p. 79) and Seiler and Tuttle (1997, p. 26). Sodium concentrations in samples collected from Army and Toulon Drains were similar to those reported by Seiler and others (1993, p. 80) but generally were higher than those of Seiler and Tuttle (1997, p. 25-26). Currently, no USEPA criteria exist for sodium. However, mallard ducklings were adversely affected by a sodium concentration of 1,500 mg/L (Micham and Wobeser 1988a, p. 41). All seven water samples collected from the unnamed drain exceeded 1,500 mg/L. No other samples exceeded this concentration.

Chloride

In general, the concentration of chloride increased with distance downstream; the highest concentrations were in samples collected from the agricultural drains (fig. 9, table 11). Chloride concentrations in Humboldt River water near Imlay, Rye Patch, and from Army Drain, Toulon Drain, and the unnamed drain were similar to those reported in previous investigations (Seiler and others, 1993, p. 79-80; Seiler and Tuttle, 1997, p. 25-26). In general, samples collected from the river near Lovelock had chloride concentrations lower than previously reported (Seiler and others, 1993, p. 79; Seiler and Tuttle, 1997, p. 26).

The acute criterion for the protection of aquatic organisms (860 mg/L) was exceeded in seven out of twelve samples collected from Army Drain and in all samples from the unnamed drain. Water collected from Toulon Drain in March 1999 (820 mg/L) approached this criterion. All samples collected from Army and Toulon Drains had chloride concentrations exceeding the chronic criterion of 230 mg/L. Eight out of 12 samples collected from the Lower Humboldt Drain exceeded the chronic chloride criterion and, in August 1999, the chloride concentration of 1,100 mg/L exceeded the acute criterion. During this study, chloride concentrations in Humboldt River water samples were below 230 mg/L, except three samples collected from the Humboldt River near Lovelock (260 to 490 mg/L).

Table 9. Minimum, median, and maximum dissolved-oxygen concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: mg/L, milligrams per liter]

Sampling site	Number of observations	Dissolved Oxygen (mg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	13	6.5	8.2	11
Humboldt River near Rye Patch	13	7.5	8.8	13
Humboldt River near Lovelock	13	7.1	8.8	13
Army Drain	13	3.3	8.4	21
Toulon Drain	13	3.8	9.4	21
Unnamed drain	7	6.3	11	27
Lower Humboldt Drain	12	4.4	7.8	14

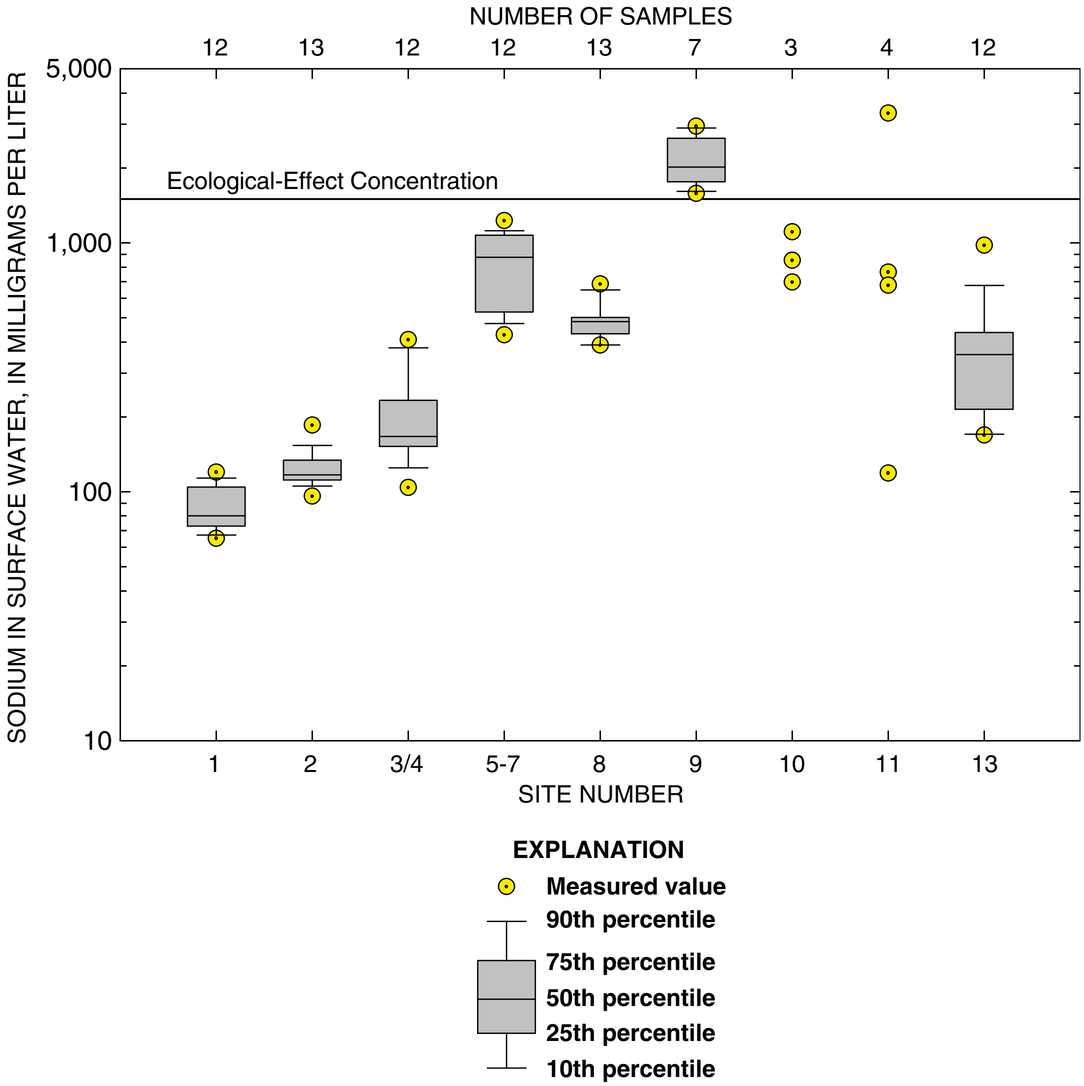

Figure 8. Sodium concentrations in surface water samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; May 1998 through July 2000. See table 1 for site descriptions.

Table 10. Minimum, median, and maximum sodium concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: mg/L, milligrams per liter]

Sampling site	Number of observations	Sodium (mg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	12	65	80	120
Humboldt River near Rye Patch	13	96	120	190
Humboldt River near Lovelock	12	100 [1]	170	410
Army Drain	12	430	880	1,200
Toulon Drain	13	390	480	680
Unnamed drain	7	1,700	2,000	2,900
Lower Humboldt Drain	12	170	360	980

[1] Sample taken in June 1998 near Reservation Road.

Dissolved solids

Dissolved-solids concentration increased with distance downstream. Agricultural drainage contained the highest concentrations (fig. 10, table 12). During this study the concentrations of dissolved solids in samples collected from the Humboldt River near Imlay, Rye Patch, and from Toulon Drain and the unnamed agricultural drain were similar to those reported for those collected from these sites in 1990 (Seiler and others, 1993, p. 79-80) and 1996 (Seiler and Tuttle 1997, p. 25-26). In general, dissolved-solids concentrations in samples collected from the river near Lovelock were lower than reported in previous investigations (Seiler and others, 1993, p. 79; Seiler and Tuttle, 1997, p. 26). However, samples collected from Army Drain had dissolved-solids concentrations similar to those reported by Seiler and others (1993, p. 80) but higher than that reported by Seiler and Tuttle (1997, p. 26).

Samples collected from the Humboldt River and Toulon Drain did not exceed the dissolved-solids ecological-effect concentration (4,900 mg/L) or the watering of livestock non-enforceable criterion (3,000 mg/L) at any time during this study. Water collected from Army Drain approached the ecological-effect concentration for dissolved solids on two occasions and 7 out of 12 samples exceeded the watering of livestock criterion. All samples collected from the unnamed drain exceeded the ecological-effect concentration and watering of livestock criterion for dissolved solids. Dissolved solids in all water samples collected from the Lower Humboldt Drain during this study were below the ecological-effect concentration. However, the watering of livestock criterion was exceeded in one sample collected on August 9, 1999.

Nutrients

Nitrogen

Total nitrogen (total-N) concentrations were calculated as the sum of (1) total ammonia plus total organic nitrogen and (2) filtered nitrate plus nitrite, expressed as N (Hem, 1985, p. 124). In calculating total-N, when the nitrate-plus-nitrite concentration was below the LRL (0.05 mg/L as N), the concentration was assumed to be negligible and assigned a value of zero. Total-N concentrations were higher in samples collected from the agricultural drains than in those collected from the Humboldt River. Total nitrogen concentrations are summarized in table 13.

Ammonia

Filtered-ammonia concentrations (un-ionized plus ionized ammonia, as N) in Humboldt River and Lower Humboldt Drain water samples ranged from less than the LRL (0.02 mg/L) to 0.09 mg/L. Agricultural drain water contained ammonia concentrations ranging from less than 0.02 to 0.95 mg/L. The criterion for the protection of aquatic life is based on the concentration of un-ionized ammonia. However, un-ionized ammonia is not directly measured and is calculated using tables relating dissolved solids, temperature, and pH to percent un-ionized ammonia (Thurston and others, 1974; Skarheim, 1973). When dissolved ammonia nitrogen was below the NWQL LRL value (0.02 mg/L) a value of 0.01 mg/L was used for the calculation of un-ionized ammonia concentration. Dissolved solids influence the concentration of un-ionized ammonia and, therefore, adjustments for total dissolved solids were made using the table from Skarheim (1973, p. 3-33). Calculated un-ionized ammonia concentrations are listed in table 14. All water samples collected as part of this study contained instantaneous un-ionized ammonia concentrations below the criterion value.

Total Phosphorus

Total phosphorus (total-P) concentrations were higher in the agricultural drains than in the Humboldt River. Toulon Drain typically contained higher concentrations of total-P than did Army Drain or the unnamed drain (table 15). Currently, no ecological criteria exist for phosphorus.

Trace Elements

In general, aluminum, antimony, chromium, copper, fluoride, iron, lead, nickel, and zinc concentrations in the Humboldt River and selected drains were within acceptable ecological and irrigation water quality criteria limits and ecological-effect concentrations. The nickel concentration in one sample collected from the unnamed drain (27 μg/L) was within the ecological-effect concentration range, 11.7 to 125 μg/L (Eisler, 2000c, p. 457). Manganese concentrations in some of the agricultural drain samples exceeded the irrigation criterion (200 μg/L). However, these waters are not intended for irrigation. Arsenic, boron, mercury, molybdenum, selenium, and uranium either exceeded ecological water-quality criteria or have been identified previously as constituents of concern. For these reasons, they are discussed separately below.

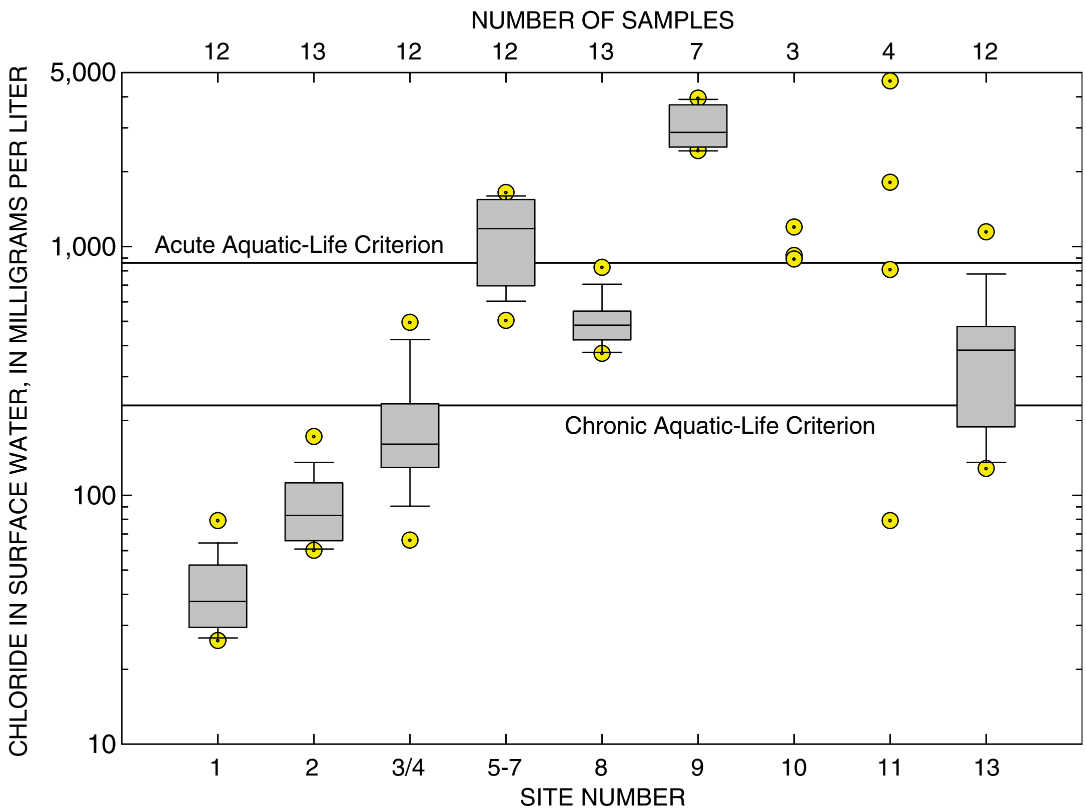

Figure 9. Chloride concentrations in surface water samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; May 1998 through July 2000. See table 1 for site descriptions. Refer to figure 8 for figure explanation.

Table 11. Minimum, median, and maximum chloride concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: mg/L, milligrams per liter]

Sampling site	Number of observations	Chloride (mg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	12	26	37	79
Humboldt River near Rye Patch	13	60	83	170
Humboldt River near Lovelock	12	66 [1]	160	490
Army Drain	12	500	1,300	1,600
Toulon Drain	13	370	480	820
Unnamed drain	7	2,400	2,900	3,900
Lower Humboldt Drain	12	130	380	1,100

[1] Sample taken in June 1998 near Reservation Road.

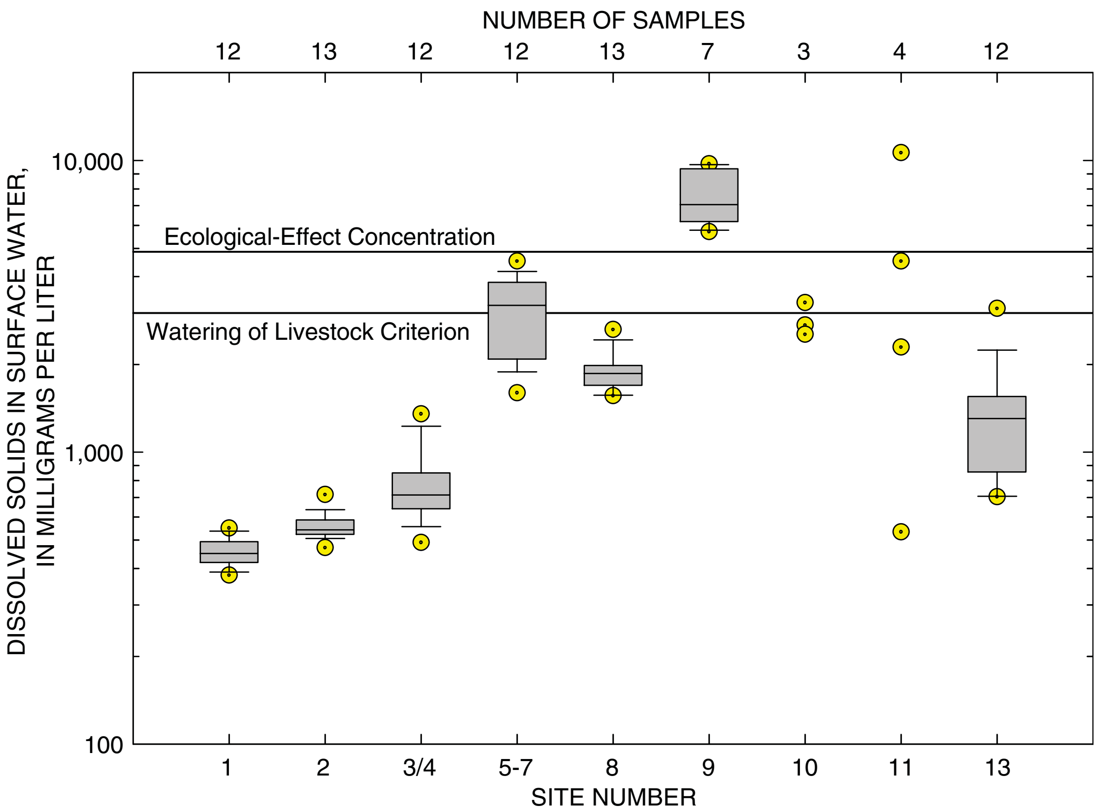

Figure 10. Dissolved-solids concentrations in surface water samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; May 1998 through July 2000. See table 1 for site descriptions. Refer to figure 8 for figure explanation.

Table 12. Minimum, median, and maximum dissolved-solids concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: mg/L, milligrams per liter]

Sampling site	Number of observations	Dissolved Solids (mg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	12	380	450	550
Humboldt River near Rye Patch	13	470	540	720
Humboldt River near Lovelock	12	490 [1]	710	1,400
Army Drain	12	1,600	3,200	4,500
Toulon Drain	13	1,600	1,900	2,600
Unnamed drain	7	5,700	7,100	9,700
Lower Humboldt Drain	12	700	1,300	3,100

[1] Sample taken in June 1998 near Reservation Road.

Table 13. Minimum, median, and maximum total-nitrogen concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: mg/L, milligrams per liter]

Sampling site	Number of observations	Total Nitrogen (mg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	12	0.18	0.66	0.99
Humboldt River near Rye Patch	12	0.26	0.66	0.90
Humboldt River near Lovelock	13	0.35	0.70	0.90
Army Drain	12	0.96	1.8	2.3
Toulon Drain	12	1.0	1.6	3.4
Unnamed drain	7	1.0	1.9	3.3
Lower Humboldt Drain	11	0.60	0.94	2.5

Table 14. Calculated minimum, median, and maximum un-ionized ammonia concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: mg/L, milligrams per liter]

Sampling site	Number of observations	Un-ionized ammonia nitrogen (mg/L) [1]		
		Minimum	Median	Maximum
Humboldt River near Imlay	12	0.00002	0.00004	0.002
Humboldt River near Rye Patch	13	0.00002	0.0003	0.003
Humboldt River near Lovelock	12	0.00004	0.0001	0.008
Army Drain	12	0.00008	0.0003	0.0006
Toulon Drain	13	0.00007	0.0004	0.002
Unnamed drain	7	0.000005	0.00004	0.0002
Lower Humboldt Drain	12	0.00003	0.0003	0.002

[1] These values were calculated using methods described by Thurston and others (1974) and adjusted for dissolved solids by methods described by Skarheim (1973).

Table 15. Minimum, median, and maximum total phosphorus concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation and symbol: mg/L, milligrams per liter]

Sampling site	Number of observations	Total Phosphorus (mg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	13	0.02	0.09	0.43
Humboldt River near Rye Patch	13	0.04	0.06	0.07
Humboldt River near Lovelock	13	0.07	0.11	0.19
Army Drain	13	0.11	0.19	0.88
Toulon Drain	13	0.15	0.33	1.1
Unnamed drain	7	0.18	0.21	0.74
Lower Humboldt Drain	12	0.03	0.11	0.59

Arsenic

Arsenic concentrations generally increased with distance downstream, with the highest measured concentrations in samples collected from the agricultural drains (fig. 11, table 16). Samples collected from Lower Humboldt Drain also contained higher concentrations of arsenic than those collected from the river. Arsenic concentrations in Humboldt River samples collected near Imlay and Rye Patch and in those from Army and the unnamed agricultural drains were similar to those reported in previous studies (Seiler and others, 1993, p. 83-84; Seiler and Tuttle, 1997, p. 28-29). Arsenic concentrations in waters collected from Toulon Drain had concentrations similar to those of Seiler and others (1993, p. 84) on March 26, 1990 (64 µg/L) and of Seiler and Tuttle (1997, p. 28) on May 20, 1996 (66 µg/L). However, arsenic concentrations were well below the concentration of 760 µg/L, reported by Seiler and others (1993, p.84) on July 09, 1990.

The ecological-effect concentration of 40 µg/L for arsenic (Birge and others, 1978, p. 98-99) was not exceeded in Humboldt River water collected near Imlay. However, this concentration was approached in three out of twelve samples collected from the Humboldt River near Rye Patch and nine out of twelve samples collected from the river near Lovelock. The ecological-effect concentration was exceeded in one sample collected from the river near Lovelock (42 µg/L), in nine out of eleven samples collected from the Lower Humboldt Drain, and in all samples from the agricultural drains. The USEPA ecological chronic arsenite (As(III)) criterion of 150 µg/L may have been exceeded in five out of seven samples collected from the unnamed drain and in one out of eleven samples collected from the Lower Humboldt Drain. However, arsenic speciation was not determined during this study and therefore criterion exceedence could not be determined. Arsenic concentrations in surface water collected from the Humboldt River and Toulon and Army Drains were below the 150 µg/L criterion. All arsenic concentrations were below the acute criterion of 340 µg/L for As(III). The criterion for the protection of livestock (200 µg/L) was exceeded in three samples collected from the unnamed drain. All samples collected from the unnamed drain, three samples from Army Drain, and one sample from Lower Humboldt Drain exceeded the arsenic criterion for irrigation waters. However, these waters are not intended for irrigation.

Boron

Median boron concentrations increased with distance downstream. Agricultural drainage contained the highest concentrations of boron (fig. 12, table 17). Boron concentrations in Humboldt River water collected near Imlay and Rye Patch as part of this study were similar to those reported in previous investigations (Seiler and others, 1993, p. 83; Seiler and Tuttle, 1997, p. 28). However, concentrations in samples from the river near Lovelock and the unnamed drain were lower than those previously reported (Seiler and others, 1993, p. 83; Seiler and Tuttle, 1997, p. 29). Concentrations in samples from Army and Toulon Drains were similar to those in samples collected in 1990 (Seiler and others, 1993, p. 84) but were a little higher than those collected in 1996 (Seiler and Tuttle, 1997, p. 28-29).

An ecological-effect concentration of 200 µg/L for boron (Birge and Black, 1977, p. 27) was exceeded in all water samples collected as part of this study. Five water samples collected from the Humboldt River near Lovelock and from all sampled drains exceeded the criterion for the long-term irrigation of sensitive crops (750 µg/L). However, these waters are not intended for irrigation. Measured boron concentrations approached the recommended criterion for the watering of livestock (5,000 µg/L) in Army Drain and, occasionally, the Lower Humboldt Drain. Water collected from the unnamed drain consistently exceeded this criterion.

Mercury

Mercury concentrations were below the NWQL's LRL (0.1 µg/L) in all waters examined, similar to concentrations in samples collected in 1990 and 1996 (Seiler and others, 1993, p. 85-86; Seiler and Tuttle, 1997, p. 28-29). Samples collected in August 1999 were analyzed using low-level mercury analysis (Olson and others, 1997; Olson and DeWild, 1999). Humboldt River water near Rye Patch contained the lowest total- and methyl- mercury concentrations whereas Army Drain contained the highest (table 18). The low-level analyses for August 1999 show that the 96-hour average mercury criterion (12 ng/L) adopted by the State of Nevada was exceeded in water collected from Toulon and Army Drains. The mercury criterion was either approached or equaled in waters collected from the

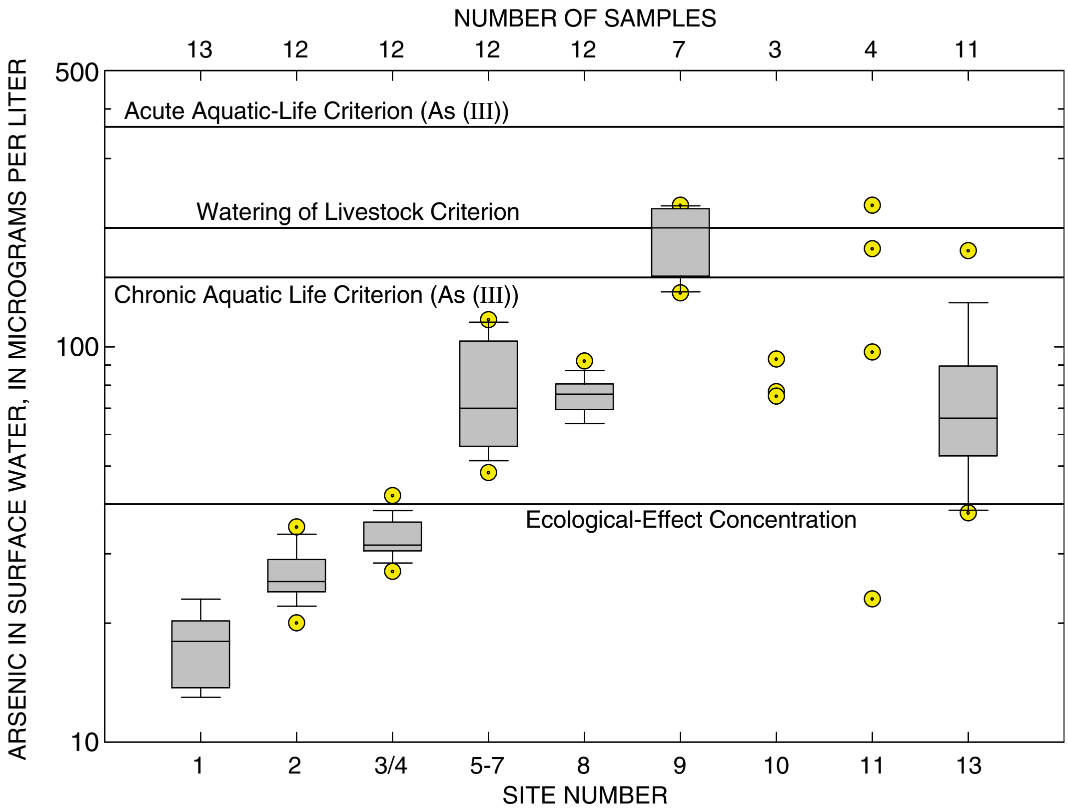

Figure 11. Arsenic concentrations in surface water samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; May 1998 through July 2000. See table 1 for site descriptions. Refer to figure 8 for figure explanation.

Table 16. Minimum, median, and maximum arsenic concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: µg/L, micrograms per liter]

Sampling site	Number of observations	Arsenic (µg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	13	13	18	23
Humboldt River near Rye Patch	12	20	26	35
Humboldt River near Lovelock	12	27	31	42
Army Drain	12	48	70	120
Toulon Drain	13	64	76	92
Unnamed drain	7	140	200	230
Lower Humboldt Drain	11	38	66	180

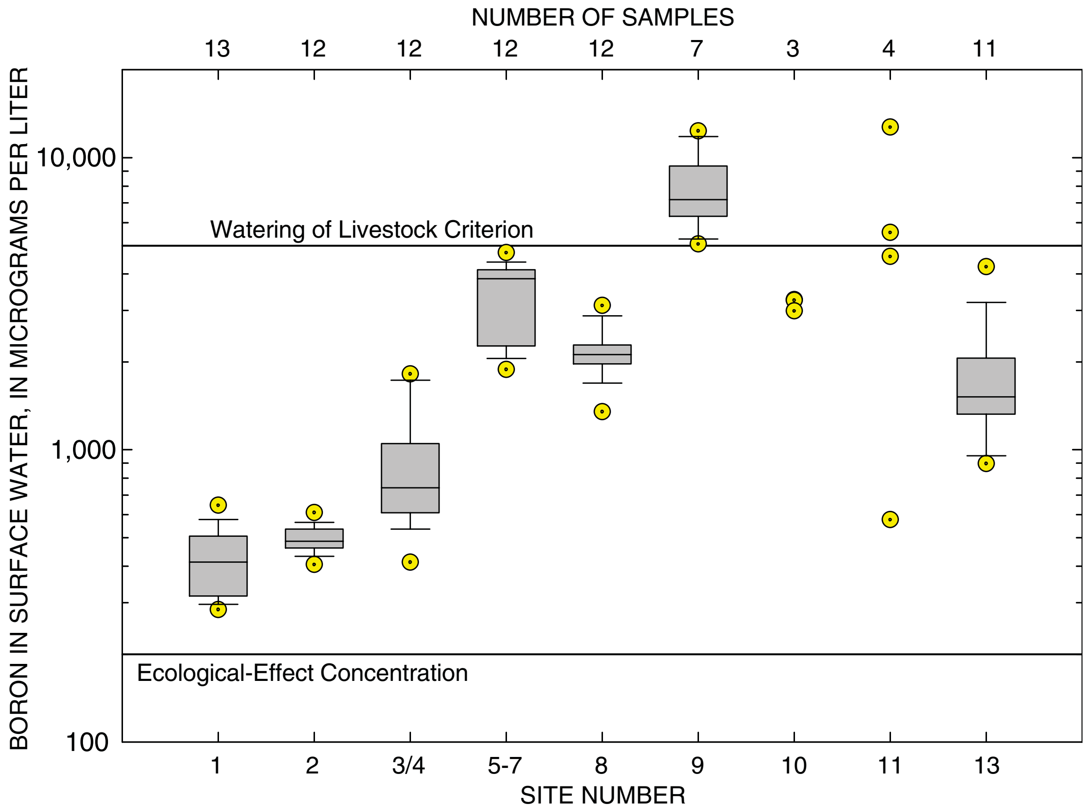

Figure 12. Boron concentrations in surface water samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; May 1998 through July 2000. See table 1 for site descriptions. Refer to figure 8 for figure explanation.

Table 17. Minimum, median, and maximum boron concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: µg/L, micrograms per liter]

Sampling site	Number of observations	Boron (µg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	13	280	410	650
Humboldt River near Rye Patch	12	400	490	610
Humboldt River near Lovelock	12	410 [1]	740	1,800
Army Drain	12	1,900	3,900	4,700
Toulon Drain	12	1,400	2,100	3,100
Unnamed drain	7	5,800	7,900	12,000
Lower Humboldt Drain	11	900	1,500	4,200

[1] Sample taken in June 1998 near Reservation Road.

river near Lovelock (10 ng/L) and from Lower Humboldt Drain (12 ng/L). Ecological-effect concentrations for mercury were not exceeded in any sample collected as part of this study.

Table 18. Total- and methyl-mercury concentrations in samples collected from the lower Humboldt River and selected drains, August 1999.

[Abbreviation and symbol: ng/L, nanograms per liter; --, not measured]

Sampling site	Mercury (ng/L) [1]	
	Methyl	Total
Humboldt River near Imlay	0.24	8.3
Humboldt River near Rye Patch	0.03	5.0
Humboldt River near Lovelock	0.33	10
Army Drain	1.3	57
Toulon Drain	0.39	14
Unnamed drain	--	--
Lower Humboldt Drain	0.31	12

[1] Routine mercury analysis performed on samples collected from June 1998 through September 1999 showed concentrations to be less than 0.1 μg/L.

Molybdenum

In general, molybdenum concentrations in samples collected as part of this study were similar to those reported for samples collected in 1996 from the Humboldt River near Rye Patch and Lovelock and from the unnamed agricultural drain (Seiler and Tuttle, 1997, p. 28-29). However, during this study molybdenum concentrations were higher in river samples collected near Imlay and Lovelock than those collected in 1990 (Seiler and others, 1993, p. 85). Additionally, concentrations were higher in water collected from Toulon Drain during this study than in 1990 and 1996 (Seiler and others, 1993, p. 85; Seiler and Tuttle, 1997, p. 28). Molybdenum concentrations in Army Drain were similar to those previously reported in the other investigations (Seiler and others, 1993, p. 86; Seiler and Tuttle, 1997, p. 29).

Currently, the USEPA does not have a molybdenum criterion. However, an aquatic-life criterion of 19 μg/L has been adopted by the State of Nevada (Adel Basham, Nevada Division of Environmental Protection, written commun., 1999). This criterion was exceeded in at least seven samples collected from each river sampling site, ten out of twelve samples collected from Army Drain, and was always exceeded in samples from Toulon, unnamed, and Lower Humboldt Drains (fig. 13). Molybdenum concentrations are summarized in table 19.

Selenium

The selenium standards adopted by the State of Nevada were not exceeded in any waters examined as part of this study (fig. 14, table 20). Selenium concentrations in Humboldt River samples typically were below the LRL (1 μg/L). Concentrations in samples from agricultural drains and Lower Humboldt Drain ranged from less than 1 to 2.9 μg/L. Selenium concentrations in samples collected from the Humboldt River near Imlay, Rye Patch, and Lovelock and from Army and Toulon Drains were similar to those reported by Seiler and others (1993, p. 85-86) and Seiler and Tuttle (1997, p. 28-29). However, samples collected from the unnamed agricultural drain as part of this study had selenium concentrations below 8 μg/L -- the value reported by Seiler and Tuttle (1997, p. 29). Six of the 31 samples collected from agricultural drains were within ecological-effect concentrations (2 to 5 μg/L; Lemly and Smith, 1987, p.9).

Uranium

Agricultural drainages had higher uranium concentrations than Humboldt River water (table 21). Samples collected from the Humboldt River and Army Drain had similar uranium concentrations to those collected by Seiler and others (1993, p. 87). However, during this study, waters from Toulon Drain had higher concentrations of uranium than were reported for samples collected in 1990 (Seiler and others, 1993, p. 87). Currently, no ecological or irrigation criteria exist for uranium.

Hydrogen and Oxygen Isotopes

Stable isotopes of water (hydrogen and oxygen) can be used to make inferences about processes that may have affected a hydrologic system, especially evaporation. Hydrogen has two stable isotopes with masses of 1 (protium) and 2 (deuterium); oxygen has three stable isotopes with masses of 16, 17, and 18. Because ^{17}O concentrations are usually small and insignificant, it is typically ignored. Only the oxygen

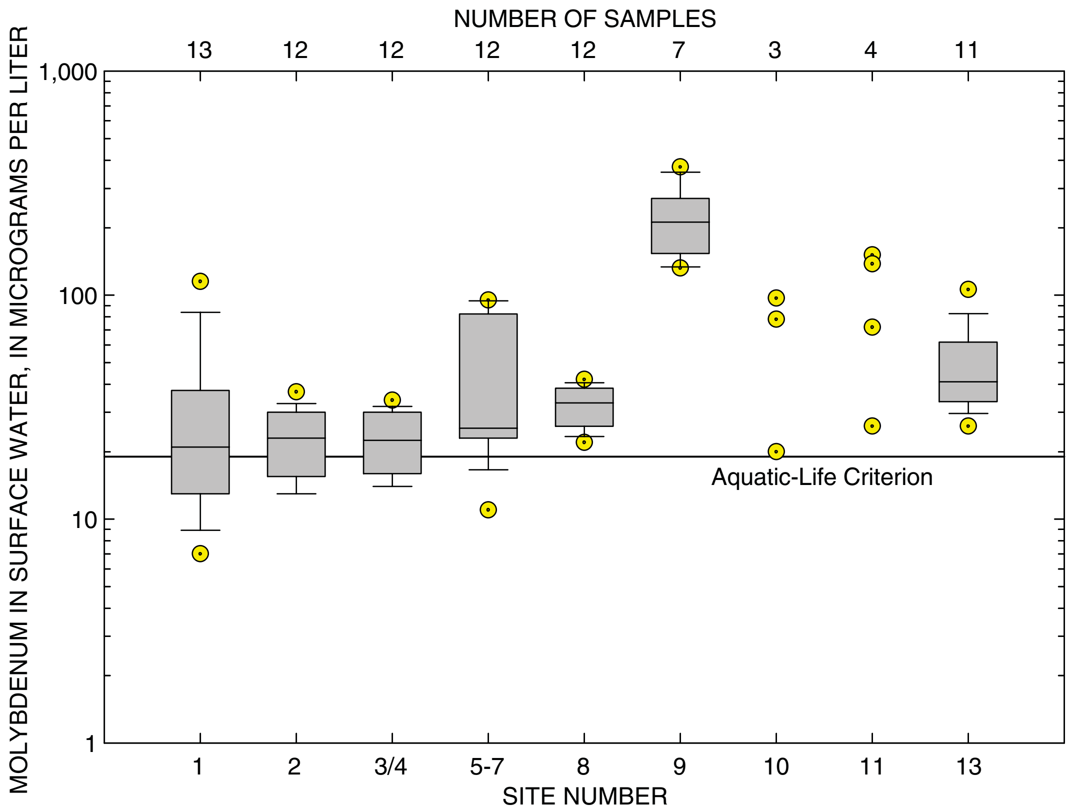

Figure 13. Molybdenum concentrations in surface water samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; May 1998 through July 2000. See table 1 for site descriptions. Refer to figure 8 for figure explanation.

Table 19. Minimum, median, and maximum molybdenum concentration in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: µg/L, micrograms per liter]

Sampling site	Number of observations	Molybdenum (µg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	13	7.0	21	120
Humboldt River near Rye Patch	12	13	23	37
Humboldt River near Lovelock	12	14	23	34
Army Drain	12	11	26	95
Toulon Drain	12	22	33	42
Unnamed drain	7	130	210	370
Lower Humboldt Drain	11	26	41	110

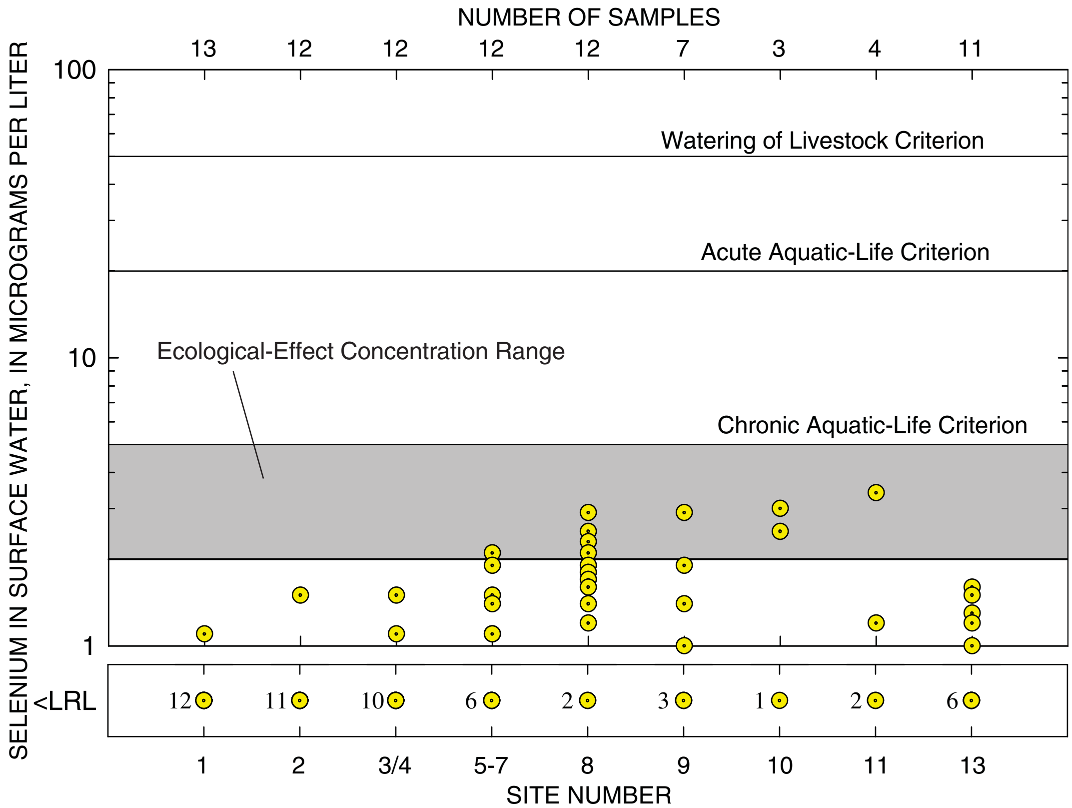

Figure 14. Selenium concentrations in surface water samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; May 1998 through July 2000. See table 1 for site descriptions. Abbreviation: <LRL, less than laboratory reporting level (number of samples are indicated for each site).

Table 20. Minimum, median, and maximum selenium concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation and symbol: µg/L, micrograms per liter; <, less than]

Sampling site	Number of observations	Selenium (µg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	12	<2.4	<2.4	<2.4
Humboldt River near Rye Patch	12	<2.4	<2.4	<2.4
Humboldt River near Lovelock	12	<2.4	<2.4	<2.4
Army Drain	12	<2.4	<2.4	<2.4
Toulon Drain	12	<2.4	<2.4	2.9
Unnamed drain	7	<2.4	<2.4	2.9
Lower Humboldt Drain	11	<2.4	<2.4	<2.4

Table 21. Minimum, median, and maximum uranium concentrations in samples collected from the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: μg/L, micrograms per liter]

Sampling site	Number of observations	Uranium (μg/L)		
		Minimum	Median	Maximum
Humboldt River near Imlay	13	2.7	4.3	6.4
Humboldt River near Rye Patch	12	4.4	5.1	6.4
Humboldt River near Lovelock	12	4.6	5.3	6.5
Army Drain	12	16	27	53
Toulon Drain	12	19	24	28
Unnamed drain	7	51	100	170
Lower Humboldt Drain	11	9.7	18	34

isotopes of masses 16 and 18 are included within this report. The stable isotopes values herein are expressed relative to a standard (Vienna Standard Mean Ocean Water), in units of parts per thousand or "permil" (Fritz and Fontes, 1980, p. 11). Because precipitation falling on northern Nevada is primarily evaporated from the Pacific Ocean, the stable-isotope composition has relatively less "heavy isotopes" (^{18}O and deuterium) than the standard and permil values are negative. Although isotopic fractionation of precipitation does occur due to changes in phase (for example, vapor to liquid to ice) and temperature, the average isotopic composition of precipitation at a site should lie close to the "meteoric-water line" (Craig, 1961), a regression line defined by the equation:

$$\delta D=8(\delta^{18}O)+10. \qquad (1)$$

The stable-isotopic composition of water samples collected for this investigation is tabulated in the appendices and shown in figure 15. The distribution of permil values extends along a linear trend from the lightest sample ($\delta^{18}O$, -15.26 permil; δD, -122 permil), collected from the Humboldt River near Imlay January 12, 1999, to the heaviest sample ($\delta^{18}O$, +0.84 permil; δD, -42.4 permil), collected from the Lower Humboldt Drain August 9, 1999. Samples from the drain are heaviest of all, with the heaviest sample collected shortly before outflow from the Humboldt Sink ceased. Quantitative evaluation of evaporation rates or volumes indicated by the isotope data is beyond the scope of this non-interpretive report.

Constituent Loading

Computed instantaneous loads were used to compare the amounts of sodium, chloride, dissolved solids, total nitrogen, total phosphorus, arsenic, boron, molybdenum, and uranium among sampling sites within the study area (table 22). The instantaneous loads (expressed in tons per day) were calculated as the product of instantaneous concentration (in milligrams per liter) and discharge (in cubic feet per second) measured at each site, times the conversion factor 0.002697 (Hem, 1985, table 8, p. 55).

The high flows in June 1998 produced the maximum amounts of sodium, chloride, dissolved solids, total nitrogen, total phosphorus, arsenic, boron, molybdenum, and uranium transported at all Humboldt River sampling sites, except total phosphorus and molybdenum near Imlay. The river, Toulon Drain, and Army Drain are the principal surface-water sources to the HWMA. During periods of high flow (greater than 130 ft^3/s) or no irrigation, the river near Lovelock generally carried greater loads of sodium, chloride, dissolved solids, total nitrogen, total phosphorus, arsenic, boron, molybdenum, and uranium to the HWMA than did the agricultural drains. However, during sampling in August 1998, when the river flow near Lovelock was 137 ft^3/s, the agricultural drains transported a larger amount of chloride to the HWMA than did the river. In September 1998 and during sampling from April through September 1999, Toulon and Army Drains carried larger amounts of sodium, chloride, dissolved solids, total nitrogen, total phosphorus, arsenic, boron, molybdenum, and uranium than did the river near Lovelock.

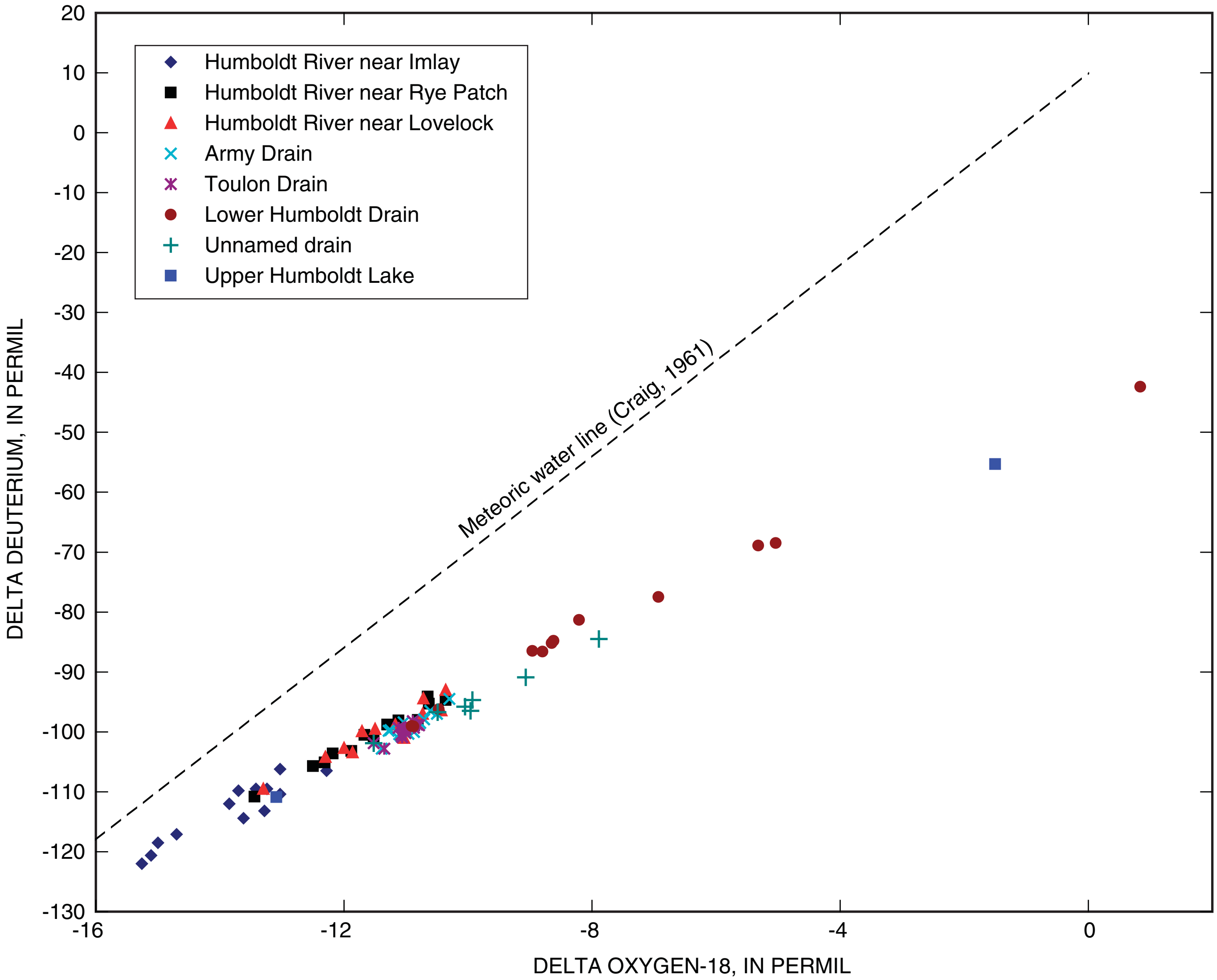

Figure 15. Stable isotopes of hydrogen and oxygen in surface-water samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; May 1998 through July 2000. See table 1 for site descriptions.

From August 1998 through January 1999, greater amounts of sodium, chloride, dissolved solids, arsenic, boron, molybdenum, and uranium were transported away from the HWMA in the Lower Humboldt Drain than the combined inputs of these constituents from the river near Lovelock and from Toulon and Army Drains to Humboldt and Toulon Lakes. Water and its solute load in Lower Humboldt Drain flow toward the Carson Sink. In March 1999, the amounts of sodium, chloride, boron, and uranium transported in the Lower Humboldt Drain again exceeded the combined inputs from the river and agricultural drains. In April and May 1999, greater amounts of sodium, dissolved solids, arsenic, boron, molybdenum, and uranium were transported in the Lower Humboldt Drain than were transported into the HWMA. During sampling in August, September, and November 1998 and in April and May 1999, greater amounts of nitrogen were transported in the Lower Humboldt Drain than by the river and drains. In August 1998 and January, April, and May 1999, greater amounts of phosphorus were carried away from the HWMA by the Lower Humboldt Drain than were transported into the HWMA. The Lower Humboldt Drain flow had ceased by September 1999.

During the overall 16-month period of intensive data collection (June 1998 – September 1999), the output of several water-quality constituents from the lower Humboldt River Basin, as indicated by median instantaneous constituent loads determined for the ephemeral flow in Lower Humboldt Drain (table 22), exceeded input to the lower basin as determined for the river near Rye Patch. Ratios of output to input for listed median loads at those two sites ranged from 0.8/1 to 2.8/1.

Table 22. Minimum, maximum, and median instantaneous discharges and calculated instantaneous loads of selected constituents at sampling sites along the lower Humboldt River and selected drains, June 1998 through September 1999.

[Abbreviation: ft^3/s, cubic feet per second]

Constituent or property		Humboldt River near Imlay	Humboldt River near Rye Patch Reservoir	Humboldt River near Lovelock	Combined Army and Toulon Drains	Lower Humboldt Drain [1]
Discharge (ft^3/s)	Minimum	45	140	18	12	0
	Median	410	520	140	50	340
	Maximum	2,000	2,400	2,100 [2]	110	940
Sodium (tons/day)	Minimum	15	46	18	29	0
	Median	73	160	50	72	320
	Maximum	510	610	580 [2]	260	430
Chloride (tons/day)	Minimum	10	32	19	41	0
	Median	34	110	45	86	310
	Maximum	250	390	380 [2]	320	450
Dissolved solids (tons/day)	Minimum	67	210	57	110	0
	Median	440	730	220	280	1,100
	Maximum	2,600	3,000	2,800 [2]	930	1,800
Total nitrogen (tons/day)	Minimum	0.029	0.16	0.017	0.055	0
	Median	0.73	0.86	0.28	0.19	0.69
	Maximum	4.8	4.2	2.6 [2]	0.50	1.4
Total phosphorus (tons/day)	Minimum	0.0049	0.026	0.018	0.0088	0
	Median	0.057	0.064	0.15	0.025	0.092
	Maximum	1.1	0.38	1.1 [2]	0.12	0.48
Arsenic (tons/day)	Minimum	0.0020	0.011	0.0020	0.0025	0
	Median	0.016	0.034	0.0091	0.0085	0.048
	Maximum	0.096	0.13	0.18 [2]	0.033	0.091
Boron (tons/day)	Minimum	0.078	0.18	0.082	0.12	0
	Median	0.34	0.62	0.25	0.32	1.3
	Maximum	2.3	2.6	2.4 [2]	1.1	2.2
Molybdenum (tons/day)	Minimum	0.0033	0.0089	0.0011	0.0010	0
	Median	0.026	0.020	0.0074	0.0034	0.032
	Maximum	0.067	0.13	0.11 [2]	0.026	0.071
Uranium (tons/day)	Minimum	0.00078	0.0025	0.00028	0.00089	0
	Median	0.0043	0.0059	0.0016	0.0031	0.014
	Maximum	0.027	0.032	0.032 [2]	0.012	0.023

[1] Flow in drain ceased in about August 1999

[2] For the sampling site, Humboldt River at Reservation Road, which is upstream from agricultural diversions.

The only ratio less than 1/1 was for total nitrogen (that is, the input of nitrogen exceeded the output). For all other listed constituents (table 22), output-to-input ratios were greater than 1/1, ranging from 1.4/1 for arsenic and total phosphorus to 2.8/1 for chloride. The 2.8/1 ratio, for example, indicates that the median instantaneous load of chloride leaving the lower basin was almost three times greater than the median incoming load.

Outflow from Humboldt Sink, by way of Lower Humboldt Drain, is ephemeral: it occurs only in and immediately after wet years (see "Hydrologic Setting"). During the study period discussed herein, the measured outflow peaked in July 1998, shortly after sampling began, and ceased a year later in about August 1999. Historically, the most recent earlier period of appreciable outflow from Humboldt Sink was in the very wet mid-1980s. Between episodes of outflow, the incoming constituents, including ones of biologic concern, accumulate in the sink (Seiler and others, 1993, p.11).

To evaluate the contribution of upstream mine dewatering on constituent loads in the lower Humboldt River, data on dewatering discharge and water quality for June 1998 through September 1999 were obtained from the Nevada Division of Environmental Protection (NDEP) discharge-monitoring reports (NV0021962, NV0022268, and NV0022675). Monthly average reported values for each mine that is permitted to discharge to the Humboldt River and its tributaries were summed to obtain a cumulative monthly discharge. Those values were multiplied by reported constituent concentrations to obtain estimated constituent loads. Only dissolved solids and total arsenic were monitored by all of the mines that discharge ground-water dewatering effluent to the river and its tributaries. Dissolved-solids and arsenic loads were summed for each month and cumulative median values obtained for the 16-month period.

Estimated cumulative mine-dewatering discharges to the Humboldt River and tributaries during June 1998-September 1999 ranged from 61 to 206 ft^3/s and averaged 108 ft^3/s (fig. 16). Average flow in the Humboldt River near Imlay was 563 ft^3/s for the same time period.

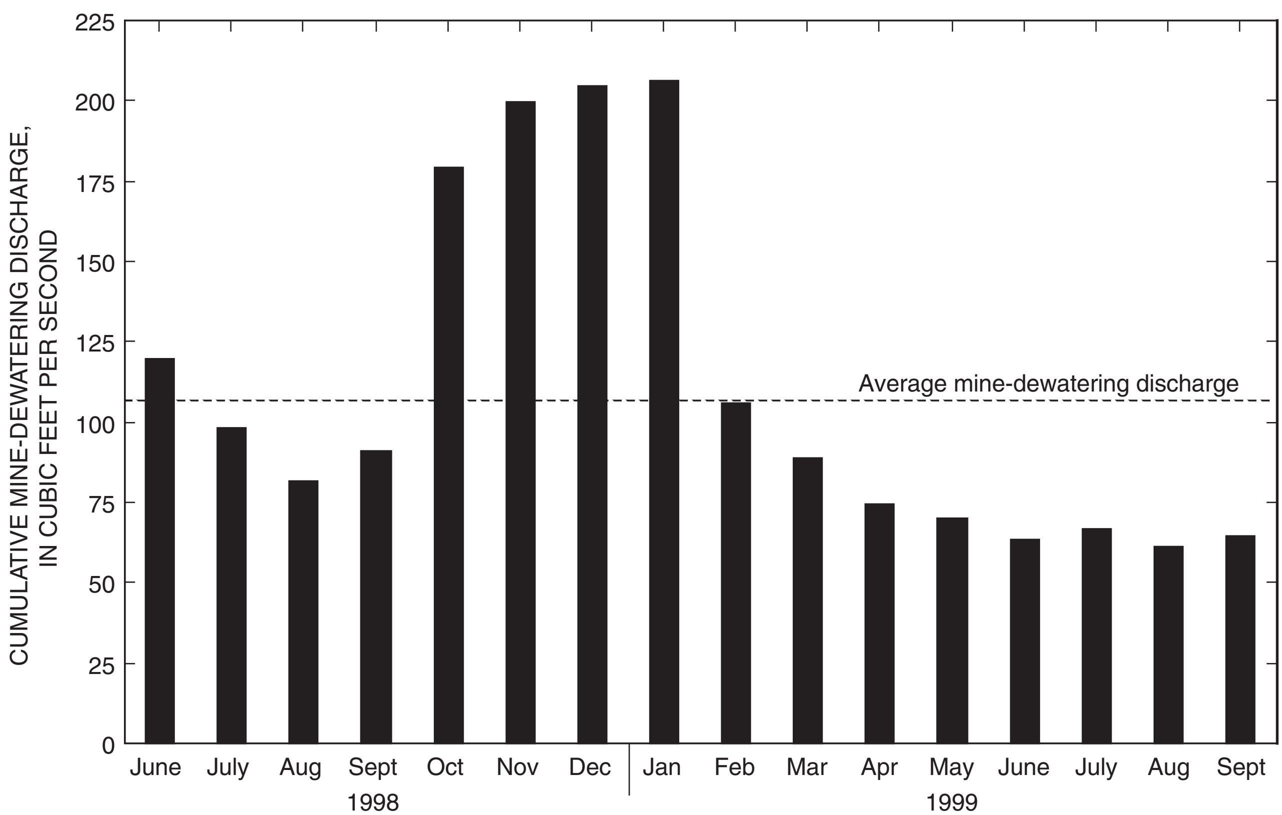

Figure 16. Graph showing estimated cumulative permitted mine-dewatering discharges to the surface waters of the Humboldt River and tributaries from June 1998 through September 1999. Data from Nevada Division of Environmental Protection mine-discharge monitoring reports (NV0021962, NV0022268, NV0022675).

Concentrations of dissolved solids and total arsenic in dewatering discharge are summarized below. Estimated median loads of dissolved solids and arsenic contributed by mine-dewatering discharge from June 1998 through September 1999 were 25 and 0.0010 tons/day, respectively. The median dissolved-solids load transported in the river near Imlay was 440 tons/day (table 22). The median (filtered) arsenic load near Imlay was 0.016 tons/day. The median Imlay loads are 18-times and 16-times the median dewatering loads, respectively.

	Arsenic (micrograms per liter)	Dissolved solids (micrograms per liter)
Number of determinations	41	40
Minimum value	<1	306
Median value	22	391
Average value	23	407
Maximum value	60	545

Bottom Sediment

Sediment samples from all Humboldt River and drain sites, except the unnamed drain, were collected in August 1998 and 1999. Sediment was collected from the unnamed drain only in August 1999. Analyses were made on the silt- and clay-sized (less than 0.62 µm) fractions. Selected constituent concentrations found in collected sediment were compared with Canadian Interim Freshwater Sediment-Quality Guidelines (ISQG) for the protection of aquatic life and with available no-effect, probable-effect, and threshold-effect concentrations (table 4). Currently, no United States sediment-quality guidelines exist. However, MacDonald and others (2000) have published consensus-based guidelines, derived from published sediment toxicity data. With the exception of arsenic and mercury, all sediments collected as part of this study had constituent concentrations below probable-effect levels (concentrations). Sediment constituents that exceeded available guidelines and threshold-effect concentrations are discussed below.

Arsenic

Sediment collected from the Humboldt River near Imlay, Rye Patch Reservoir, and Lovelock had arsenic concentrations ranging from 6.7 to 15 µg/g. The highest concentrations of arsenic associated with river sediments were found near Rye Patch. Agricultural drain sediments collected in August 1998 and August 1999 contained arsenic concentrations ranging from 12 to 21 µg/g. Lower Humboldt Drain sediment had arsenic concentrations of 17 µg/g in August 1998 and 21 µg/g in August 1999. Arsenic concentrations less than or equal to 8.2 µg/g are reported to have no effect on biota and 17 µg/g is reported as the probable-effect level (U.S. Department of the Interior, 1998, table 1; Canadian Council of Ministers of the Environment, 1999, table 1). All sediment-arsenic concentrations exceeded the ISQG for arsenic (5.9 µg/g), figure 17. Sediment collected from Army and Lower Humboldt Drains in August 1999 exceeded the Canadian probable-effect level for arsenic. Except those collected near Imlay, all sediments sampled from the lower Humboldt River system had arsenic concentrations above the consensus-based threshold-effect concentration (9.79 µg/g). Sediment-arsenic concentrations found during this study were similar to those reported previously for samples collected near Imlay, Rye Patch Reservoir, and Lovelock (Seiler and others, 1993).

Cadmium

During this study, sediments collected from the Humboldt River had cadmium concentrations ranging from 0.40 to 0.70 µg/g. Generally, Army and Toulon Drain sediments had the highest cadmium concentrations, 0.60 to 0.94 µg/g. With the exception of Army Drain in August 1998 (0.80 µg/g), cadmium concentrations in sediments collected in August 1998 were essentially at or below the ISQG (0.6 µg/g), figure 18. However, with the exception of those collected from the unnamed drain (0.51 µg/g) and Lower Humboldt Drain (0.47 µg/g), sediments collected in August 1999 contained cadmium concentrations (0.67 to 0.94 µg/g) above the ISQG. Although sediment cadmium concentrations were found to exceed the ISQG in some sediments, concentrations were always below the threshold-effect concentration (0.99 µg/g, MacDonald and others, 2000, table 2). Cadmium concentrations in sediments collected in November 1990 were less than 2 µg/g (Seiler and others, 1993, p. 89).

Chromium

Chromium concentrations found in Humboldt River sediments ranged from 42 to 52 µg/g in August 1998 and from 51 to 62 µg/g in August 1999. In August 1998, the highest measured concentration of chromium in river sediments was found in the sample collected near Rye Patch. In August 1999, river sediment near

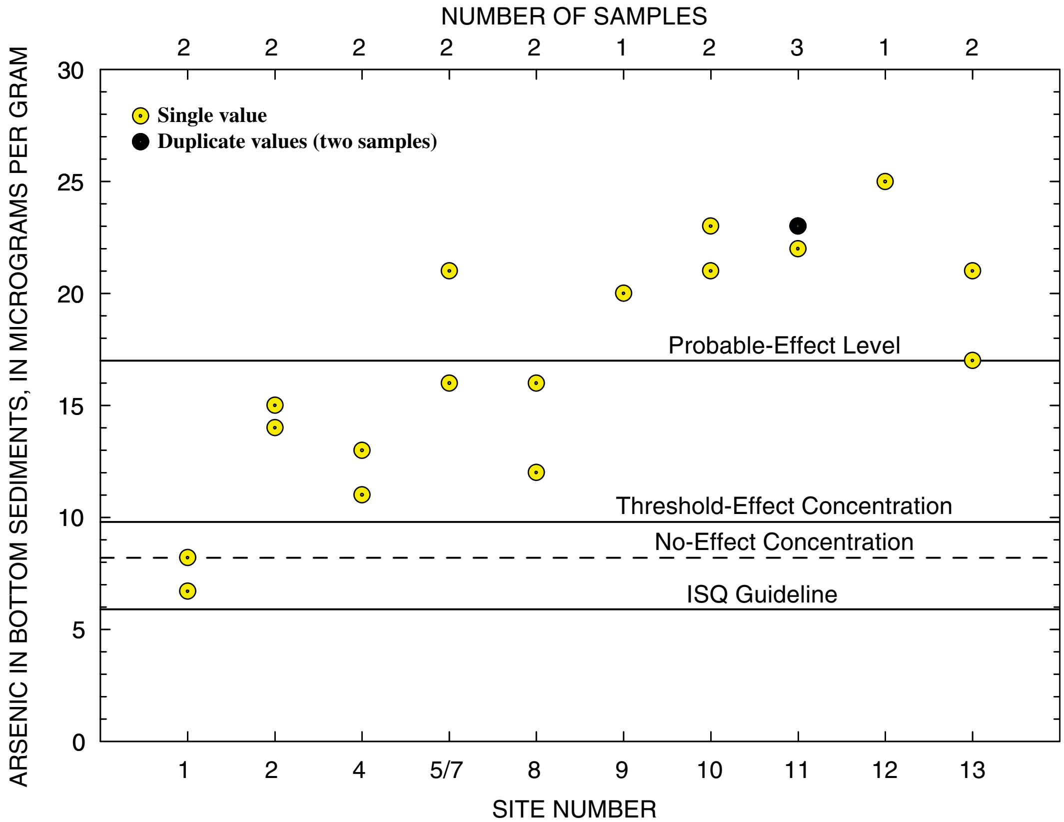

Figure 17. Arsenic concentrations in sediment (<62 µm) samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; August 1998, August 1999, and April and July 2000. ISQ Guideline is Canadian Interim Freshwater Sediment-Quality Guideline. See table 1 for site descriptions.

Lovelock contained the highest measured chromium concentration. The lowest concentration of chromium in river sediment was found near Imlay. Chromium concentrations in agricultural drain sediments ranged from 42 to 52 µg/g. Lower Humboldt Drain had the lowest concentrations of any river or drain site sampled during this study: 29 and 28 µg/g, respectively, for August 1998 and 1999. Except for sediments from the Lower Humboldt Drain, all samples collected from the river and selected drains exceeded the ISQG for chromium (37.3 µg/g; Canadian Council of Ministers of the Environment, 1999, table 1), figure 19. With the exception of sediments collected from near Imlay and Toulon Drain in August 1998 and those from the unnamed drain in August 1999, concentrations of chromium in sediments exceeding the ISQG also were above the consensus based threshold-effect concentration (43.4 µg/g, MacDonald and others, 2000, table 2). In general, chromium concentrations found in sediments collected from the Humboldt River near Lovelock and from Army and Toulon Drains were greater than previously reported (44, 39, and 41 µg/g, respectively) by Seiler and others (1993, p. 89).

Copper

Copper associated with Humboldt River sediments ranged from 18 to 25 µg/g in August 1998 and from 30 to 38 µg/g in August 1999. The lowest concentrations were for those near Rye Patch. Agricultural-drain sediments had the highest concentrations. In August 1998, sediments collected from Toulon and Army Drains had copper concentrations of 29 and 39, respectively (the unnamed drain was not sampled). In August 1999, agricultural-drain sediments had copper concentrations ranging from 39 to 45 µg/g and the highest concentration was found in the sample collected from the unnamed drain. Sediments collected from the Humboldt River near Lovelock and from Toulon Drain and the unnamed drain in August 1999 and from Army Drain in August 1998 and 1999 exceeded the ISQG (35.7 µg/g) and the threshold-effect concentration (31.6 µg/g, MacDonald and others, 2000,

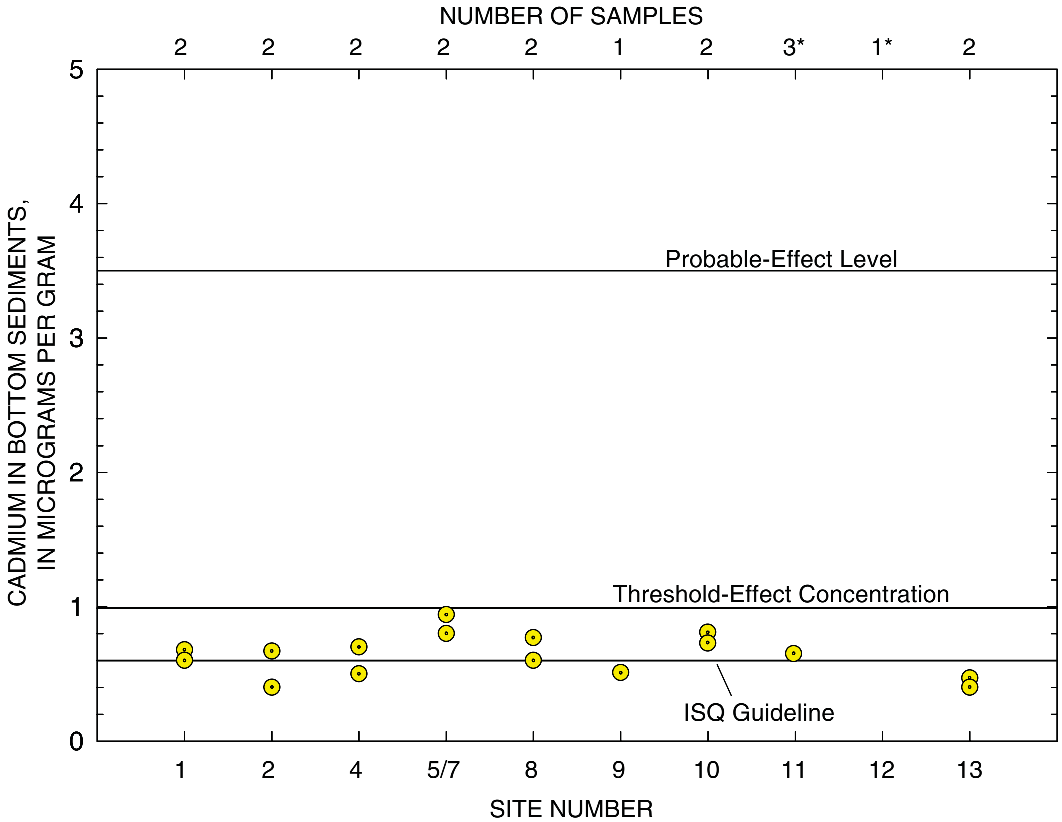

Figure 18. Cadmium concentrations in sediment (<62 µm) samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; August 1998, August 1999, and April and July 2000. ISQ Guideline is Canadian Interim Freshwater Sediment-Quality Guideline. See table 1 for site descriptions.

table 2). Sediment collected from near Imlay in August 1999 had a copper concentration above the threshold-effect concentration (fig. 20). Copper concentrations generally were higher in sediments collected in this study than in the reconnaissance investigation in 1990 (16 to 29 µg/g; Seiler and others, 1993, p. 89).

Mercury

Using conventional analytical methods, mercury concentrations in the less-than-62 µm fraction of wet-sieved sediments collected in 1998 and 1999 for all sites ranged from 0.03 to 0.14 µg/g. In August 1998, the sample collected from the Humboldt River near Lovelock had the highest sediment mercury concentration (0.08 µg/g). In August 1999, sediment from the Lower Humboldt Drain had the highest mercury concentration (0.14 µg/g). In general, mercury concentrations in sediments collected as part of this study were similar to those reported previously (Seiler and others, 1993, p. 90).

Separate sediment samples collected in August 1999 were analyzed for mercury using a low-level method (Olson and others, 1997; Olson and DeWild, 1999). These analyses were made on bulk sediment samples that were not wet-sieved. The low-level data showed that Humboldt River sediment mercury concentrations ranged from 0.0058 to 0.69 µg/g. Army, Toulon, and Lower Humboldt Drain concentrations were 0.039, 0.57, and 0.18 µg/g, respectively. For the concurrent bottom-sediment samples that were sieved and analyzed using conventional methods, mercury concentrations at the river sites ranged from 0.06 to 0.10 µg/g, and concentrations for the three drains were 0.06, 0.11, and 0.14 µg/g, respectively. As indicated on p. 10 and 16, sample collection and analysis procedures for the conventional and low-level determinations differed appreciably.

Sediment methyl-mercury concentrations ranged from 0.000041 to 0.0023 µg/g. Sediments collected from Toulon Drain and from the Humboldt River near Lovelock contained the highest and the lowest concentrations of methyl-mercury, respectively.

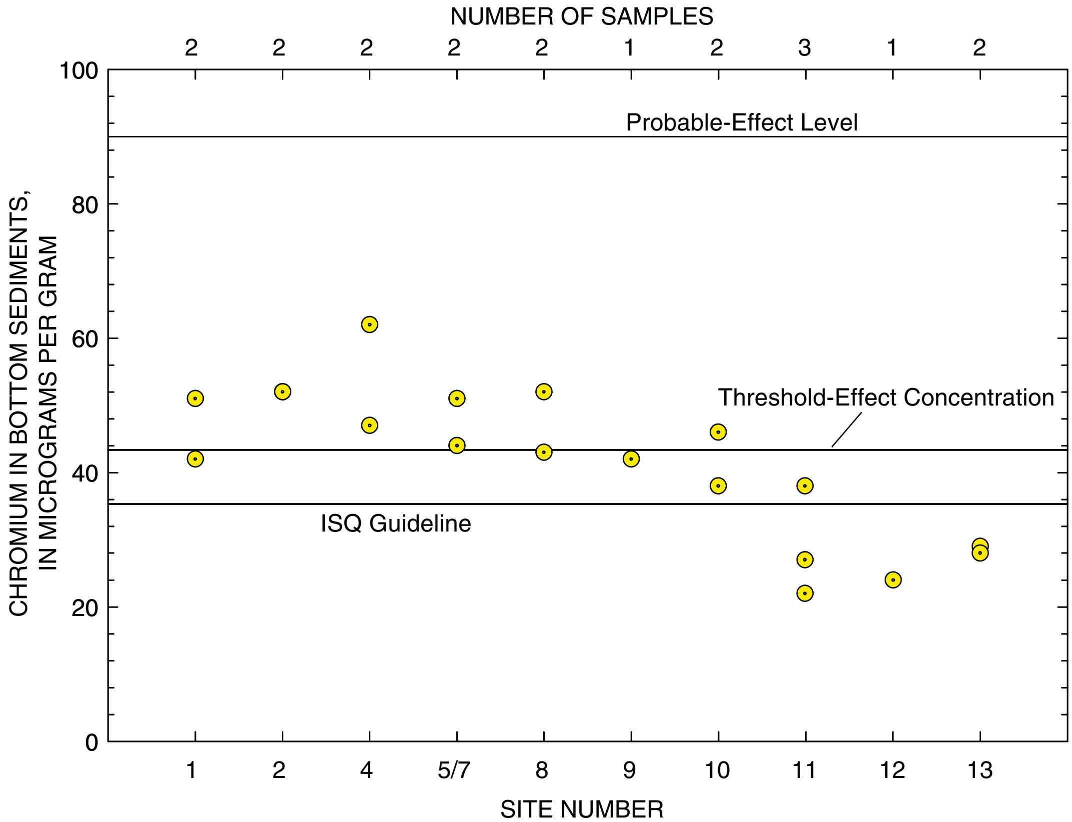

Figure 19. Chromium concentrations in sediment (<62 µm) samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; August 1998, August 1999, and April and July 2000. ISQ Guideline is Canadian Interim Freshwater Sediment-Quality Guideline. See table 1 for site descriptions.

The ISQG for mercury is 0.17 µg/g (Canadian Council of Ministers of the Environment, 1999, table 1). Mercury concentrations less than 0.065 µg/g have no known effect on biota, and 0.18 µg/g is the toxicity threshold (U.S. Department of the Interior, 1998, table 20; MacDonald and others, 2000, table 2). Sediments collected from the Humboldt River near Lovelock and the Lower Humboldt Drain in August 1998 and those from near Imlay, the Lower Humboldt Drain, and Toulon Drain in August 1999 had mercury concentrations above the no-effect concentration. The low-level analysis results indicate that sediments collected from the Humboldt River near Imlay and from Toulon Drain in August 1999 exceeded the ISQG, threshold-effect, and probable-effect values for mercury (fig. 21).

Nickel

Concentrations of nickel in sediments collected within the lower Humboldt River system during this study ranged from 21 to 29 µg/g. In general, nickel concentrations in sediments collected as part of this study were higher than in sediments collected in 1990 (Seiler and others, 1993, p. 91). Currently, no ISQG exists for nickel. However, the consensus-based threshold-effect concentration is 22.7 µg/g (MacDonald and others, 2000, table 2). Except for samples collected from the river near Rye Patch in August 1998 (21 µg/g) and from Lower Humboldt Drain in August 1999 (22 µg/g), analyzed river and drain sediments had nickel concentrations exceeding the threshold-effect concentration (fig. 22). All sediment nickel concentrations were below the probable-effect level (48.6 µg/g, Macdonald and others, 2000, p. 24).

Selenium

Selenium was detected in all sediments collected in August 1998 and 1999. Humboldt River sediments collected in August 1998 contained selenium concentrations ranging from 0.29 to 0.32 µg/g. In August 1999, concentrations of selenium in river sediment col-

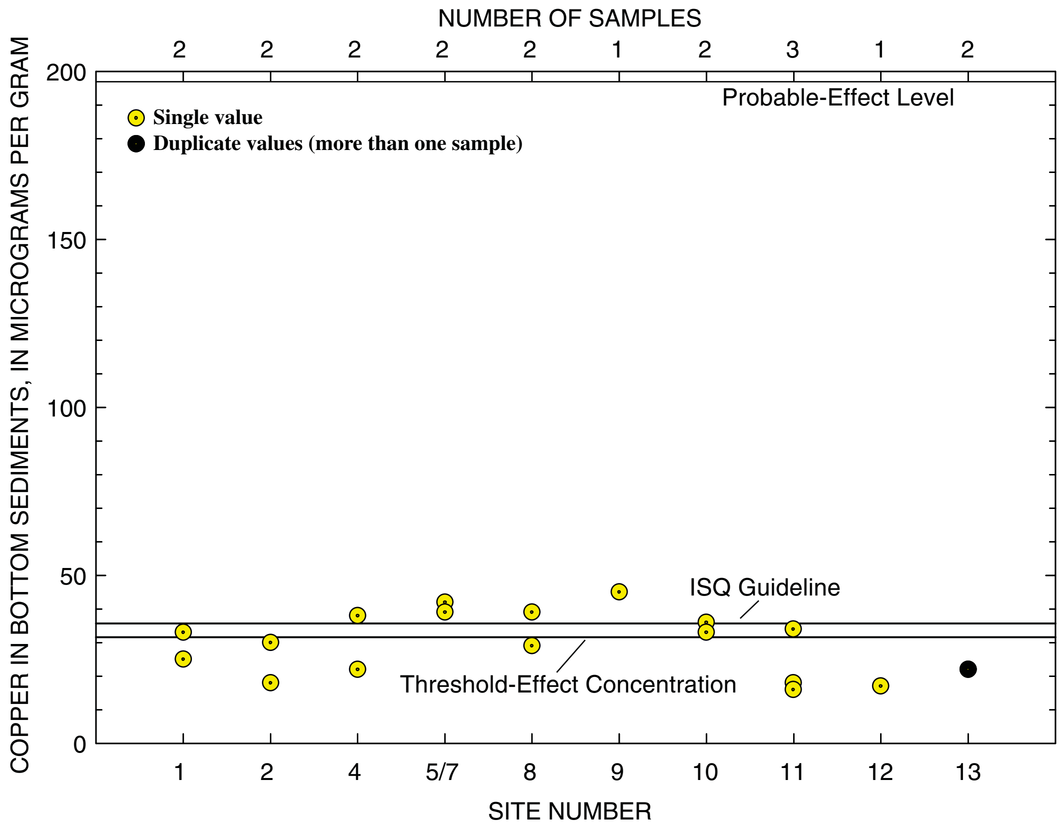

Figure 20. Copper concentrations in sediment (<62 µm) samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; August 1998, August 1999, and April and July 2000. ISQ Guideline is Canadian Interim Freshwater Sediment-Quality Guideline. See table 1 for site descriptions.

lected near Imlay, Rye Patch Reservoir, and Lovelock contained selenium concentrations of 0.42, 0.57, and 0.37 µg/g, respectively. In August 1998, Toulon and Army Drain sediment samples had selenium concentrations of 0.82 and 0.80 µg/g, respectively. Sediment collected in August 1999 from Toulon and Army Drains and the unnamed drain contained selenium concentrations of 1.1, 0.85, and 0.75 µg/g, respectively. Lower Humboldt Drain sediment selenium concentrations were 0.58 µg/g (August 1998) and 0.66 µg/g (August 1999). Selenium concentrations less than 1 µg/g have no known effect on biota, and 4 µg/g is the ecological-effect concentration (Lemly and Smith, 1987, p. 9, table 2). In general, all samples collected from the Humboldt River and selected drains as part of this study had selenium concentrations at or below the no-effect and ecological-effect concentrations (fig. 23), and the values were similar to those found in sediments collected as part of the reconnaissance investigation in 1990 (Seiler and others, 1993, p. 91).

Upper Humboldt Lake Wetland

Surface Water

Surface-water samples were collected from Upper Humboldt Lake near the mouth of the Humboldt River in May 1998. In August 1999 and in April and July 2000, samples were collected from the lake near the mouths of the Humboldt River and Army Drain. Selected constituents of concern found in Upper Humboldt Lake surface water are tabulated in table 23.

Wetland dissolved-oxygen concentration averaged 9.8 ±5.6 mg/L (125 ±88 percent saturation). The specific conductance of water from Upper Humboldt Lake ranged from 890 to 17,000 µS/cm and mean pH was 8.4 ±0.4.

Sodium, chloride, dissolved solids, arsenic, boron, molybdenum, and uranium concentrations in surface-water samples collected near the mouth of the Humboldt River in May 1998 were lower than those for samples collected in August 1999 and in April and July 2000. Sodium and molybdenum concentrations in sam-

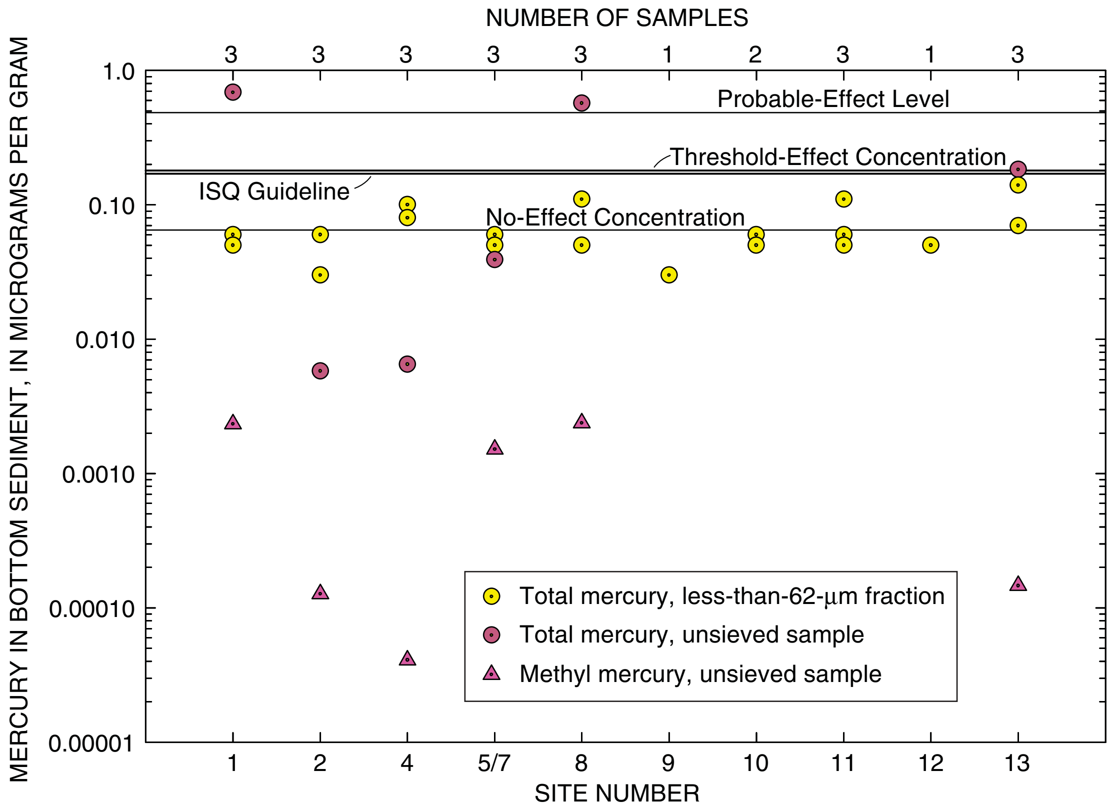

Figure 21. Mercury concentrations in sediment samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; August 1998, August 1999, and April and July 2000. ISQ Guideline is Canadian Interim Freshwater Sediment-Quality Guideline. See table 1 for site descriptions.

Table 23. Summary of concentrations of selected constituents found in filtered surface waters collected from Upper Humboldt Lake: May 1998, August 1999, and April and July 2000.

[Abbreviations and symbols: mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; --, not determined]

Constituent	Near mouth of Humboldt River				Near mouth of Army Drain		
	05/21/98	08/31/99	04/20/00	07/21/00	08/31/99	04/20/00	07/21/00
Sodium (mg/L)	120	760	680	3,300	1,110	850	670
Chloride (mg/L)	79	1,800	810	4,600	890	1,200	920
Dissolved solids (mg/L)	530	4,500	2,290	10,600	2,700	3,300	2,500
Arsenic (µg/L)	23	180	97	230	93	77	75
Boron (µg/L)	580	5,500	4,600	13,000	3,200	3,300	3,000
Mercury (µg/L)	<0.1	<0.1	--	--	<0.1	--	--
Molybdenum (µg/L)	26	150	72	140	97	78	20
Selenium (µg/L)	<1	3.4	1.2	<2.4	2.5	3.0	<2.4
Uranium (µg/L)	5	50	16	37	38	48	12

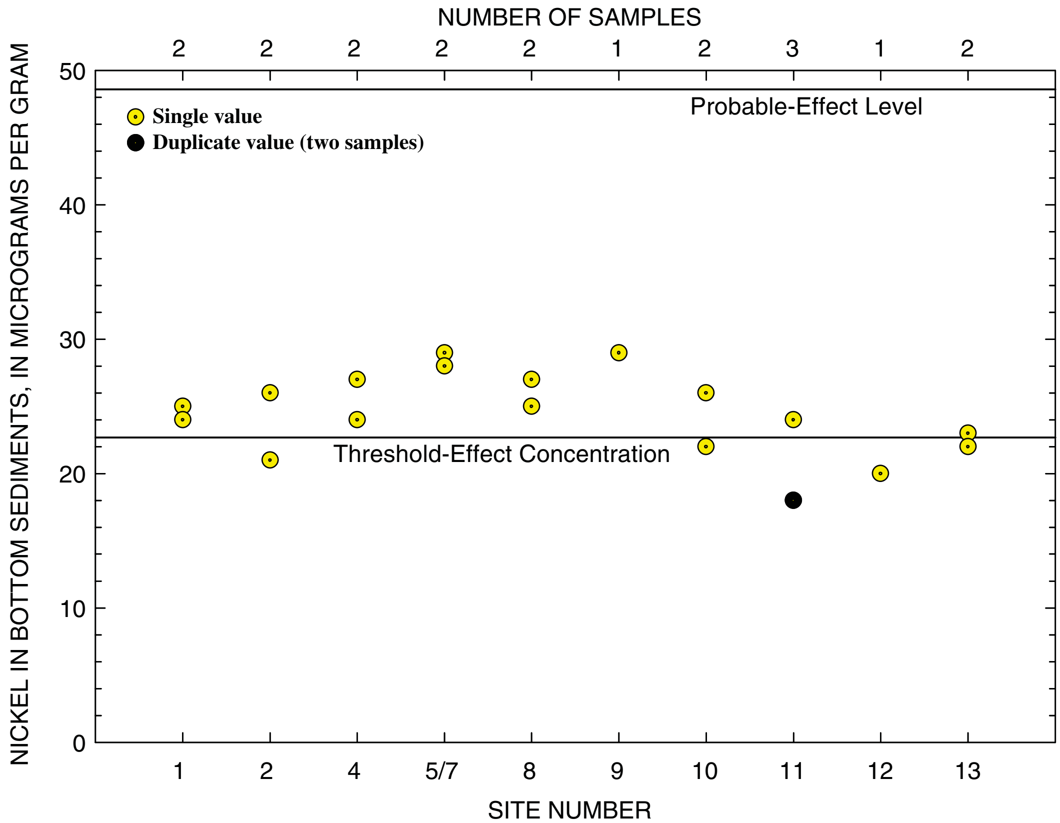

Figure 22. Nickel concentrations in sediment (<62 µm) samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; August 1998, August 1999, and April and July 2000. See table 1 for site descriptions.

ples collected at the mouth of Army Drain decreased from August 1999 to July 2000. Concentrations of arsenic and boron generally were greater near the river mouth than near the mouth of Army Drain. In May 1998 and August 1999, mercury concentrations were below the LRL (0.1 µg/L) in all samples collected; samples were not analyzed for mercury in April or July 2000. Selenium concentrations were similar in water collected near the mouths of the Humboldt River and Army Drain, ranging from less than the LRL (1 and 2.4 µg/L) to 3.4 µg/L (table 23). In general, sodium, arsenic, and boron concentrations in samples collected from near the mouth of Army Drain were similar to those from the drain. However, concentrations of molybdenum, selenium, and uranium were higher in samples from near the mouth of Army Drain than in those collected from the drain. Generally, sodium, chloride, dissolved solids, arsenic, boron, molybdenum, selenium, and uranium concentrations were higher in samples collected near the mouth of the Humboldt River than in those collected from the river near Lovelock. Samples collected as part of this study generally had lower concentrations of sodium and chloride than those reported in previous investigations (Seiler and others, 1993, p. 80; Seiler and Tuttle, 1997, p. 27). However, concentrations of arsenic, boron, and mercury were similar to those determined by Seiler and others (1993, p. 84-85) and Seiler and Tuttle (1997, p. 30). Dissolved-solids concentrations in wetland samples collected from near the mouths of Army Drain and the river were similar to those reported by Seiler and others (1993, p. 80) and lower than the value reported by Seiler and Tuttle (1997, p. 27). Molybdenum concentrations in Upper Humboldt Lake were higher than those determined during the reconnaissance investigation in 1990 (Seiler and others, 1993, p. 86) and lower than the concentration reported by Seiler and Tuttle (1997, p. 30). Selenium concentrations were higher in samples collected near the mouths of Army Drain and the Humboldt River than in those collected near the center of Upper Humboldt Lake (Seiler and others, 1993, p. 86; Seiler and Tuttle, 1997, p. 30). Uranium concentrations were higher in wetland samples collected during this study than in samples collected in 1990 (Seiler and others, 1993, p. 87).

Ecological criteria or effect concentrations for sodium, chloride, dissolved solids, arsenic, boron, molybdenum, and selenium were exceeded in Upper

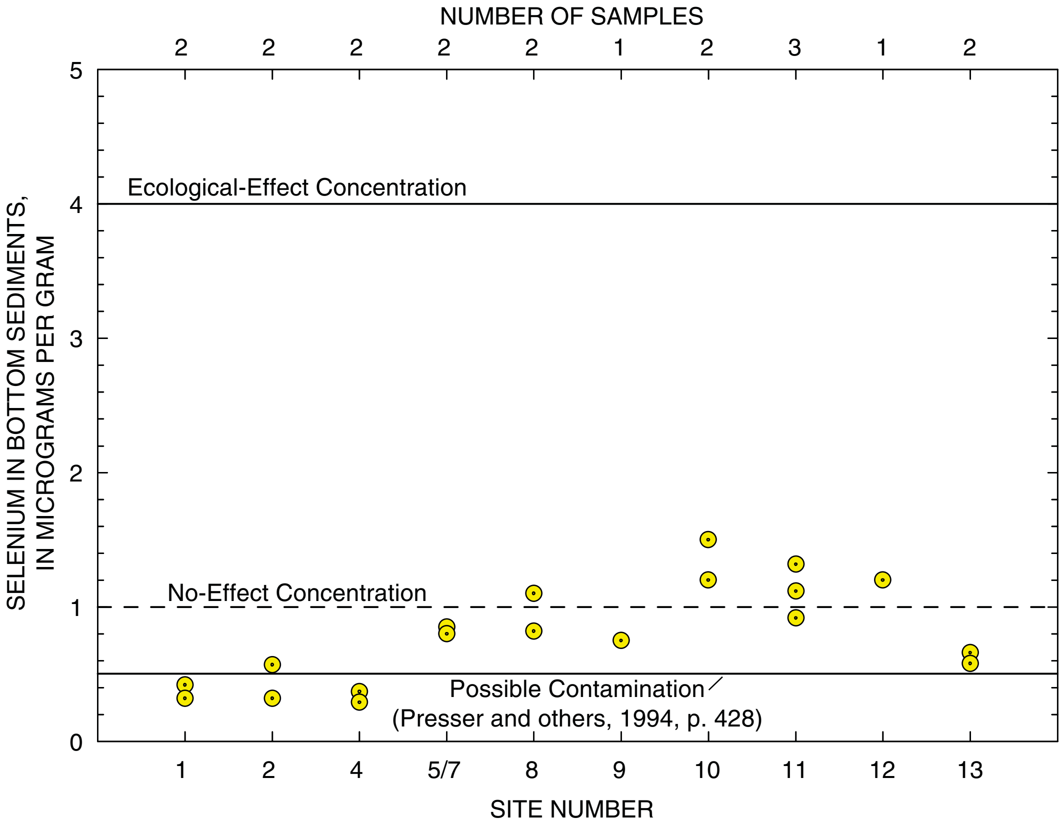

Figure 23. Selenium concentrations in sediment (<62 μm) samples collected from the lower Humboldt River, selected drains, and Upper Humboldt Lake; August 1998, August 1999, and April and July 2000. See table 1 for site descriptions.

Humboldt Lake wetland waters collected near the mouths of the Humboldt River and Army Drain (figs. 8-14). Water collected near the river mouth on July 21, 2000, exceeded the ecological-effect concentration for sodium (1,500 mg/L) and dissolved solids (4,900 mg/L). The non-enforceable dissolved-solids criterion for the protection of livestock (3,000 mg/L) was exceeded in samples collected from near Army Drain and the Humboldt River. Both the acute (860 mg/L) and chronic (230 mg/L) aquatic life criteria for chloride were exceeded in samples collected from Upper Humboldt Lake. The ecological-effect concentration for arsenic (40 μg/L) was exceeded in waters collected from Upper Humboldt Lake. However, the exceedence of protective criteria, which are based on arsenite concentrations, could not be established because arsenic speciation was not determined. All wetland samples collected as part of this study exceeded the boron ecological-effect concentration (200 μg/L). In August 1999 and July 2000, the boron criterion for the watering of livestock (5,000 μg/L) was exceeded in wetland samples collected near the mouth of the Humboldt River. On April 20, 2000, the manganese concentration in the sample collected from near the inflow of Army Drain exceeded the irrigation criterion of 200 μg/L. However, this water is not intended for irrigation. Molybdenum concentrations in Upper Humboldt Lake water samples always exceeded the Nevada molybdenum criterion for the protection of aquatic organisms (19 μg/L). Three out of seven samples collected from the wetland (2.5 to 3.4 μg/L) had concentrations within the ecological-effect range for selenium (2 to 5 μg/L).

Bottom Sediment

Wetland sediments were collected in August 1999 and in April and July 2000 near the mouths of the Humboldt River and Army Drain, and from a site near the center of Upper Humboldt Lake. Arsenic, mercury, and

selenium concentrations were similar among the three sampling sites. In general, samples collected near the mouth of Army Drain had higher concentrations of cadmium, chromium, copper, lead, lithium, molybdenum, uranium, and zinc than samples collected near the mouth of the river. Boron was evaluated only in August 1999; sediment collected near the Humboldt River had a greater boron concentration than that collected near Army Drain. In July 2000, the sample collected from near the center of Upper Humboldt Lake generally had constituent concentrations lower than or similar to samples collected near the river inflow. In general, arsenic, cadmium, chromium, copper, mercury, nickel, selenium, lead, and zinc concentrations were similar between sediments collected from near the mouth of Army Drain and those from the drain. Copper, mercury, nickel, boron, and lithium concentrations in sediments near the mouth of the Humboldt River generally were similar to those in sediments collected from the river near Lovelock. In general, concentrations of molybdenum and uranium were higher in collected wetland sediments than in samples from either the drain or the river near Lovelock. Arsenic and selenium concentrations were higher in wetland sediments collected from near the mouth of the river than in sediments collected from the river near Lovelock. In general, with the exceptions of chromium, copper, and nickel, wetland sediments contained similar constituent concentrations as those from the previous investigations in 1990 and 1996. Samples collected during this study had higher concentrations of these substances than the samples collected in 1990 and 1996 (Seiler and others, 1993, p. 89; Seiler and Tuttle, 1997, p. 31, 35).

Constituents that exceeded available guidelines, probable-effect levels, and threshold-effect concentrations are shown in figures 17 through 23. Arsenic concentrations in all wetland sediments collected as part of this study exceeded the ISQG for the protection of aquatic life (5.9 μg/g) and the probable-effect level (17 μg/g). All sediments collected near the mouth of Army Drain exceeded the ISQG for cadmium (0.6 μg/g) and chromium (37.3 μg/g). Sediments collected near the river mouth on April 20, 2000, exceeded these criteria. Only the wetland sediments collected near the mouth of Army Drain on April 20, 2000, had a chromium concentration above the threshold-effect concentration. Copper concentrations in sediments collected there were above the ISQG and threshold-effect concentrations in August 1999. Copper concentrations in sediments collected near both mouths to Upper Humboldt Lake exceeded the threshold-effect concentration in April 2000. Total mercury concentrations in wetland sediment ranged from 0.03 to 0.11 μg/g, which were below the ISQG (0.17 μg/g). The sample collected near the river on April 20, 2000, had a mercury concentration exceeding the no-effect concentration. Sediments collected near the mouths of Army Drain and the Humboldt River had nickel concentrations above the threshold-effect concentration in August 1999 and April 2000, respectively. Generally, wetland-sediment selenium concentrations were greater than the no-effect concentration (1 μg/g). Except for arsenic, constituent concentrations in wetland sediments collected during this study were below probable-effect levels.

SUMMARY

This study was initiated in May 1998 in response to the results of previous investigations of the general quality of surface water, bottom sediment, and biota in and near the Humboldt Wildlife Management Area. The objectives of this study were to (1) more extensively characterize the quality of surface water and bottom sediment in the lower Humboldt River, selected drains, and HWMA wetland; (2) determine instantaneous loads for sodium, chloride, dissolved solids, total nitrogen, total phosphorus, arsenic, boron, molybdenum, and uranium entering and leaving the HWMA; and (3) estimate the discharge from an unnamed agricultural drain into Army Drain.

During this study, streamflow in the Humboldt River system was either at or above average. Discharge of the unnamed drain into Army Drain, as determined from June 1999 through September 2000 (3 to 16 ft^3/s) contributed a small amount to the total flow measured in Army Drain (5 to 111 ft^3/s).

In general, concentrations of sodium, chloride, dissolved solids, arsenic, boron, and uranium in the river increased with distance downstream and concentrations were higher in sampled agricultural drainage than in water collected from the river. Concentrations of sodium, chloride, dissolved solids, arsenic, boron, mercury, selenium, and uranium generally were similar to concentrations reported in previous investigations. Ecological criteria for chloride, arsenic, boron, mercury, and molybdenum were exceeded in some samples collected as part of this study, as summarized in table 24. Additionally, the non-enforceable watering of livestock criterion for dissolved solids was exceeded in a number of samples collected from Army Drain, the unnamed agricultural drain, and Lower Humboldt Drain.

At all river sampling sites, the high flows measured in June 1998 transported the study-period maximum instantaneous loads of sodium, chloride, dissolved solids, total nitrogen, total phosphorus, arsenic, boron, molybdenum, and uranium, except for the total-phosphorus and molybdenum loads at the Imlay site. Greater amounts of sodium, chloride, dissolved solids, total nitrogen, total phosphorus, arsenic, boron, molybdenum, and uranium generally were

transported in river water near Lovelock than by either Toulon or Army Drains during periods of high flow (greater than 130 ft^3/s) or no irrigation.

During most of the study period, sodium, dissolved-solids, arsenic, boron, molybdenum, and uranium loads in the Lower Humboldt Drain exceeded the combined load carried in the river near Lovelock, Toulon Drain, and Army Drain. Occasionally, greater amounts of chloride, nitrogen, and phosphorus were transported by the Lower Humboldt Drain than by the river and agricultural drains. Flow in the Lower Humboldt Drain was negligible in September 1999.

From June 1998 through September 1999 estimated cumulative permitted mine-dewatering discharges to the surface waters of the Humboldt River and its tributaries ranged from 61 to 206 ft^3/s. Median total dissolved solids and total arsenic transported within this effluent were approximately 25 and 0.0010 tons/day, respectively. Median dissolved-solids and (filtered) arsenic loads determined for this time period for the Humboldt River near Imlay were 440 and 0.016 tons/day, respectively.

Bottom sediments were collected from the Humboldt River and selected drains in August 1998 and 1999. Sediment arsenic, cadmium, chromium, copper, and mercury concentrations that exceeded ISQG guidelines or probable-effect levels are summarized in tables 25 and 26, respectively. Nickel concentrations in collected sediments exceeded the consensus-based threshold-effect levels (22.7 μg/g), except in the Humboldt River near Rye Patch and in the Lower Humboldt Drain in August 1998. Although selenium was detected in all sediments collected during this study, all concentrations were below the ecological-effect concentration (4 μg/g). All other constituent concentrations in sediments collected as part of this study were within acceptable criteria limits. Concentrations of arsenic, mercury, and selenium in sediments collected for this study were similar to those previously reported. In contrast, concentrations of chromium, copper, and nickel generally were higher in sediments collected during this study than in those collected during the reconnaissance investigation in 1990.

Wetland surface-water samples were collected near the mouths of the Humboldt River and Army Drain to Upper Humboldt Lake. Those collected near the river mouth in May 1998 had lower sodium, chloride, dissolved solids, arsenic, boron, molybdenum, and uranium concentrations than samples collected in August 1999 or in April and July 2000. During sampling in August 1999 and April and July 2000, concentrations of arsenic and boron were greater near the river mouth than near the mouth of Army Drain. All samples collected from Upper Humboldt Lake had similar selenium concentrations, ranging from less than 1 μg/L to 3.4 μg/L. Mercury concentrations in samples collected from the wetland were below the minimum LRL (0.1 μg/L). Concentrations of sodium, chloride, dissolved solids, molybdenum, selenium, and uranium concentrations in wetland samples collected during this study differed from those reported in previous investigations. However, concentrations of arsenic, boron, and mercury were similar to concentrations in samples collected in the earlier studies. Ecological criteria or effect concentrations for chloride, dissolved solids, arsenic, boron, molybdenum, and selenium were exceeded in wetland waters of Upper Humboldt Lake collected near the mouths of the Humboldt River and Army Drain. Constituents exceeding protective ecological criteria are summarized in table 24.

Wetland sediment samples were collected in August 1999 and in April and July 2000 from two to three sampling locations within Upper Humboldt Lake. Arsenic, mercury, nickel, and selenium concentrations were similar among the three sampling sites. In general, sediments collected near the mouth of Army Drain to Upper Humboldt Lake had higher concentrations of cadmium, chromium, copper, lead, molybdenum, nickel, uranium, and zinc than sediments collected near the river mouth. In July 2000, sediment collected from near the center of Upper Humboldt Lake had lower or similar constituent concentrations to those collected from the lake near the mouth of the Humboldt River. With the exception of chromium and nickel, all wetland sediment concentrations from the reconnaissance investigation in 1990 and those collected during this study generally were similar. Wetland sediment arsenic, cadmium, chromium, and copper concentrations exceeding the ISQG or probable-effect levels are summarized in tables 25 and 26. Two out of six sediment samples collected from Upper Humboldt Lake exceeded the consensus-based threshold-effect concentration (22.7 μg/g) for nickel. Selenium concentrations in wetland sediment were essentially at the biological no-effect concentration of 1 μg/g. All other wetland sediment constituent concentrations were within acceptable criteria limits.

Table 24. Summary of constituents in surface water collected during this study that exceeded ecological criteria in the lower Humboldt River system.

[Abbreviations and symbols: mg/L, milligrams per liter; µg/L, micrograms per liter; --, sample not collected for low level mercury analysis]

Constituent (and ecological criterion)	Number of samples in which criterion concentration was exceeded/total number of samples								
	Humboldt River near Imlay	Humboldt River near Rye Patch	Humboldt River near Lovelock	Army Drain	Toulon Drain	Unnamed Drain	Upper Humboldt Lake near Army Drain	Upper Humboldt Lake near Humboldt River	Lower Humboldt Drain
Chloride (230 mg/L) [1]	0/12	0/13	3/12	12/12	13/13	7/7	3/3	3/4	8/12
Dissolved Solids (3,000 mg/L) [2]	0/12	0/13	0/12	7/12	0/13	7/7	1/3	2/4	1/12
Arsenic (200 µg/L) [3]	0/13	0/12	0/12	0/12	0/12	3/7	0/3	1/4	0/11
Boron (5,000 µg/L) [2]	0/13	0/12	0/12	0/12	0/12	7/7	0/3	2/4	0/11
Mercury (0.012 µg/L) [4]	0/1	0/1	0/1	1/1	1/1	--	--	--	0/1
Molybdenum (19 µg/L) [5]	7/13	8/12	8/12	10/12	12/12	7/7	3/3	4/4	11/11

[1] This value is the USEPA (1998) chronic 96-hr average chloride criterion (http://www.epa.gov/fedregst/EPA_WATER/1998/December/Day-10/w30272.htm).

[2] These criteria are for waters used to water livestock (Nevada Bureau of Water Quality Planning, 1998)

[3] The acute and chronic aquatic life criteria for arsenic are based on arsenite concentrations. Arsenic speciation was not determined during this study and therefore exceedence of these criteria could not be established. However, the criterion for the watering of livestock is not dependent on arsenic speciation and is therefore included in this table.

[4] Low-level mercury concentrations were determined for water samples collected from the lower Humboldt River, Army Drain, Toulon Drain, and Lower Humboldt Drain in August 1999. The aquatic life criterion of 0.012 µg/L, was exceeded where indicated but the frequency at which collected samples exceeded this criterion is unknown due to the LRL (0.1 µg/L) associated with routine mercury analysis.

[5] This criterion value is intended to be protective of aquatic life (Nevada Bureau of Water Quality Planning, 1998).

Table 25. Summary of constituents in sediments collected during this study at concentrations exceeding Canadian Interim Freshwater Sediment-Quality Guidelines (ISQG) in the lower Humboldt River system.

[Abbreviations and symbols: µg/g, microgram per gram; --, sample not collected]

Constituent (ISQG in µg/g)	Number of samples in which guideline concentration was exceeded/Total number of samples									
	Humboldt River near Imlay	Humboldt River near Rye Patch	Humboldt River near Lovelock	Army Drain	Toulon Drain	Unnamed Drain	Upper Humboldt Lake near Army Drain	Upper Humboldt Lake near Center	Upper Humboldt Lake near Humboldt River	Lower Humboldt Drain
Arsenic (5.9)	2/2	2/2	2/2	2/2	2/2	1/1	2/2	1/1	3/3	2/2
Cadmium (0.6)	1/2	1/2	1/2	1/2	2/2	0/1	2/2	0/1	1/3	0/2
Chromium (37.3)	2/2	2/2	2/2	2/2	2/2	1/1	2/2	0/1	1/3	0/2
Copper (35.7)	0/2	0/2	1/2	1/2	2/2	1/1	1/2	0/1	0/3	0/2
Mercury [1] (0.17)	1/1	0/1	0/1	0/1	1/1	--	--	--	--	1/1

[1] Exceedence of this criterion value based on low-level mercury analysis data.

Table 26. Summary of constituents in sediments collected during this study at concentrations exceeding probable-effect levels (PELs) in the lower Humboldt River system.

[Abbreviations and symbols: mg/g, microgram per gram; "--", sample not collected]

Constituent (PEL in µg/g)	Number of samples in which the PEL concentration was exceeded/Total number of samples									
	Humboldt River near Imlay	Humboldt River near Rye Patch	Humboldt River near Lovelock	Army Drain	Toulon Drain	Unnamed Drain	Upper Humboldt Lake near Army Drain	Upper Humboldt Lake near Center	Upper Humboldt Lake near Humboldt River	Lower Humboldt Drain
Arsenic (17.0)	0/2	0/2	0/2	1/2	0/2	1/1	2/2	1/1	3/3	1/2
Mercury [1] (0.486)	1/3	0/3	0/3	0/3	1/3	--	--	--	--	0/2

[1] Exceedence based on low-level mercury analysis data.

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